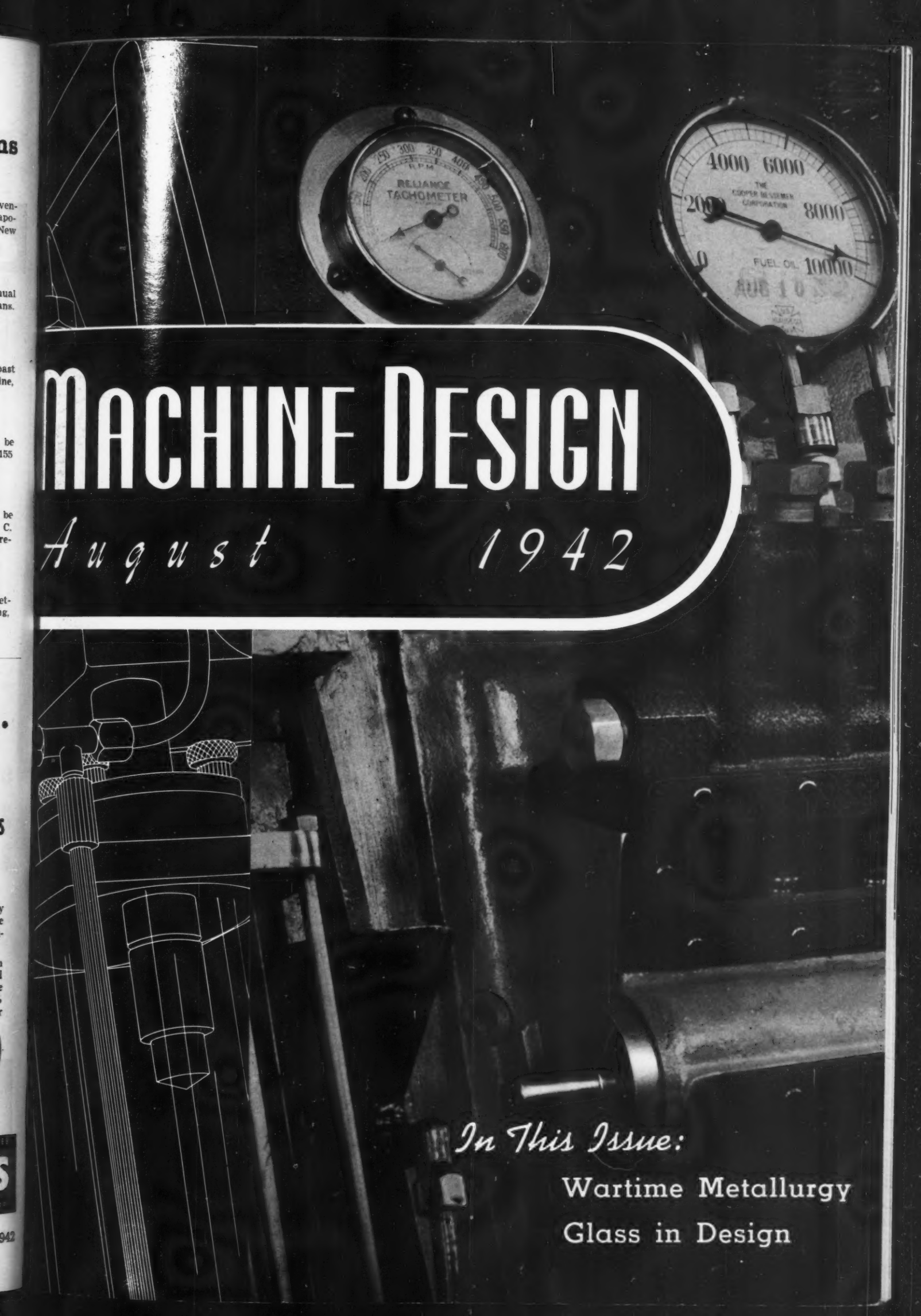

MACHINE DESIGN

August *1942*

In This Issue:

Wartime Metallurgy

Glass in Design

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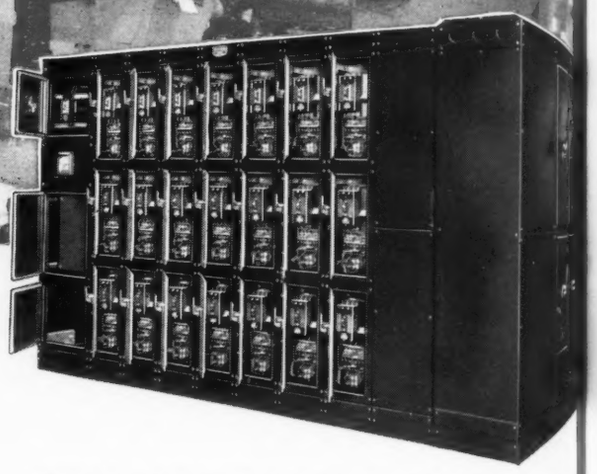

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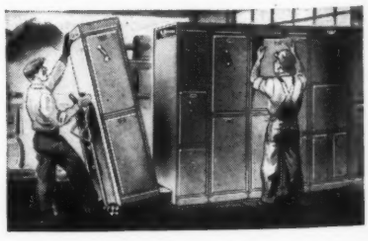

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Volume 14 AUGUST, 1942 Number 8

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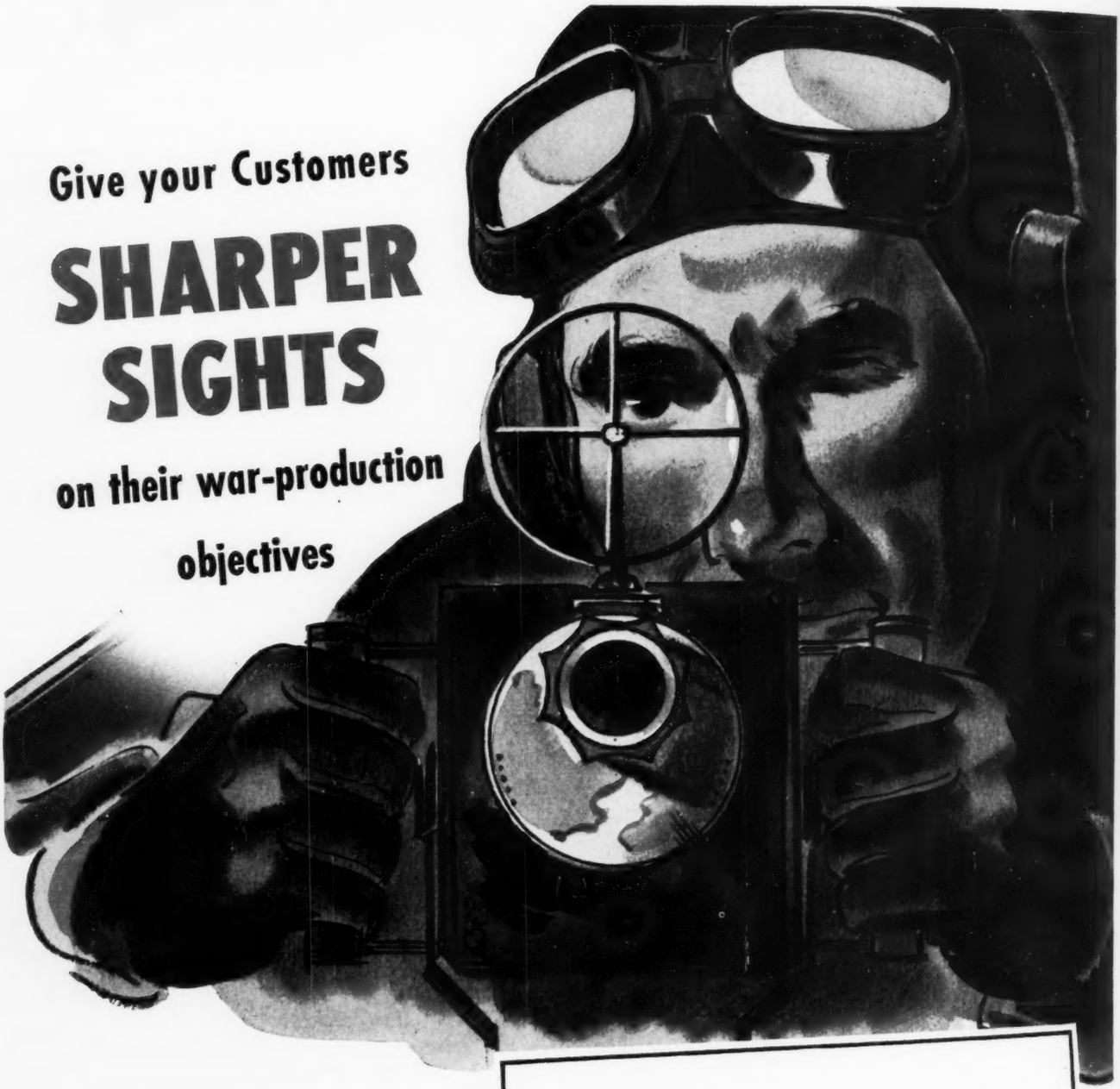

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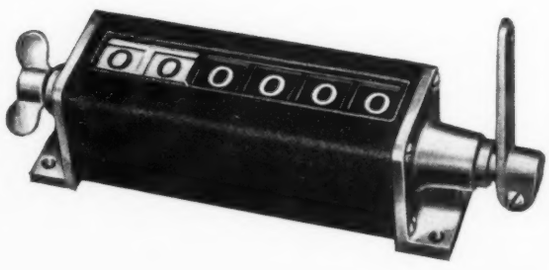

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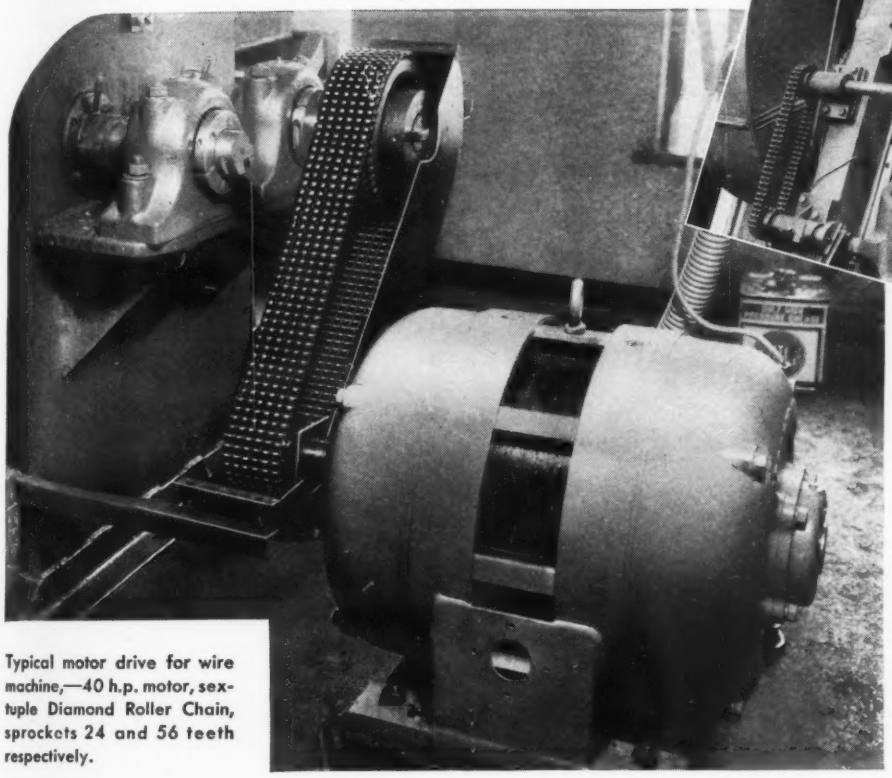

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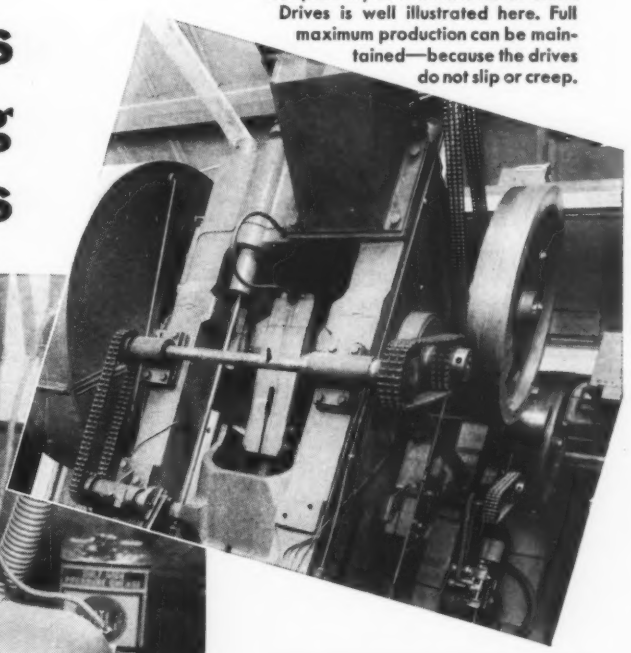

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Production in 1942 has greater significance than for any period in our history. Every bit of extra production makes Victory closer,—every effort to accomplish this is worth immediate investigation.

Look to your machines.—Are they running under maximum output speeds and dropping lower gradually because of slip in the drives? Are they stopped too frequently for adjustments and replacements? Do they waste power and tax power supply?

You can insure operating at maximum output with Diamond High Speed Drives and maintain this output for the duration, because there is no slipping with Diamond Roller Chain, no chance of dropping down to a lower productive rate. Time-outs for replacements are saved because of longer life,—maintenance is reduced,—and because efficiency remains at 98-99%, power is conserved.

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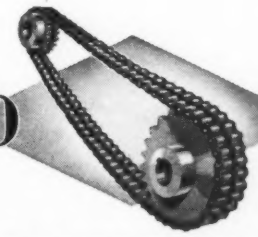

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PLASTIC films .00002-inch thick, equal to about one tenth the length of yellow-orange light waves have been found best by General Electric scientists for revealing details of metal surfaces under the electron microscope. By magnifying details as much as 20,000 times, important knowledge about metals for war uses has already been revealed. After being polished and etched a metal sample is dipped immediately in a solution of Formvar in dioxane solvent. Evaporation of the solvent leaves a film of the plastic which is stripped for study. Thinner films, although following the irregularities of the specimen have a uniform thickness. Thicker films have one plane surface but proportionately reduce the change in thickness caused by the hills and valleys in the test sample. The best thickness to reveal most detail is the thinnest film that will develop a plane top surface. Previous failures to obtain satisfactory results is attributed to lack of appreciation of this fact. Thickness is controlled by amount of solvent used.

•

WAR shipments by the automotive industry were 46 per cent greater in April than in February, based on War Production Board reports by 432 plants comprising automobile and truck manufacturers and parts companies. These companies reported shipments of $420,000,000 of which 83 per cent were war goods.

•

TIN, electric power and labor can be conserved by a new commercial electrolytic process for plating strip steel, according to E. I. du Pont de Nemours and Co. Plating is accomplished twice as fast with less power than by the alkaline method. By using a neutral solution, sludging common to many methods is eliminated, thereby conserving precious tin. A thinner, more uniform coat is applied than by hot dip methods, allowing a saving of over 40 per cent. Subsequent heating for bright finish or lacquering causes no discoloration.

•

DAIRY and milk handling equipment is playing an increasingly important part in the war program according to the York Ice Machinery Co. Heat exchangers, for example, which are ordinarily used for cooling milk are being applied to the cooling of alcohol as it comes from the stills and in the cooling of many other liquids now being produced in volume for war production.

•

INVENTORIES frozen by wartime regulation can now be sold without receiving further authorization from Washington nor reporting such sales if they are of the specified types covered by Priorities Regulation No. 13. This regulation sets up uniform rules governing the sale of idle inventories of certain kinds and removes such sales from existing regulations which affect the normal flow of material. In this way it is expected that hundreds of thousands of tons of critical materials will be freed for vital war production.

•

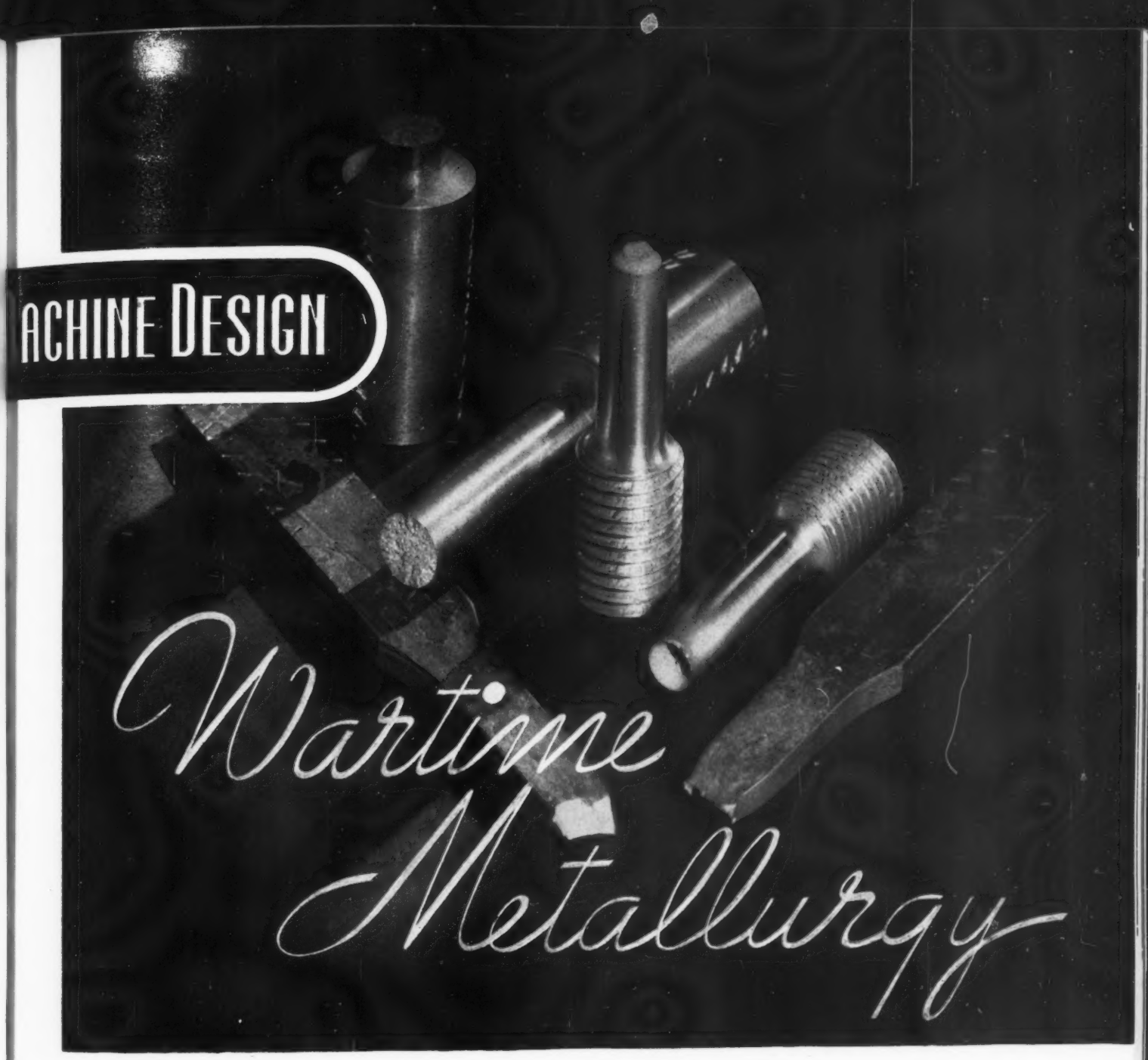
BECAUSE wood and woodworking machinery are becoming increasingly important in war industries, General Limitation Order L-3 has been extended to cover this field. Technical advances in the manufacture and application of plywood, for example, have increased the demand tremendously for aircraft and boat construction as well as other parts for war weapons. Approved orders for machines include those for the Army and Navy, certain government agencies, the governments of the United Nations, lend-lease requirements and other high rating orders.

•

VALUE of metalworking machinery shipped during May was $118,500,000 as announced by the War Production Board. Production rates are steadily increasing and at the present are more than 65 per cent over those of last year. Compared with the same month a year ago, the increase is 80 per cent.

•

FIBER body cans are now produced on the machinery formerly used for metal containers, according to a recent announcement of the American Can Co. Restrictions on tin and metal containers as well as on new machinery make this development particularly noteworthy at this time. By producing a reasonable facsimile of the old containers it is possible also to use existing filling and packaging machinery, preventing a crucial bottleneck for the manufacturers of packaged dry products.



Conserves Strategic Materials

Part I

By R. E. Orton and W. F. Carter
Acme Steel Co., Chicago

OUR country is suffering today from critical shortages of the alloying elements for steel. Unquestionably these alloys have been used in excessive amounts, and these excesses now are spelling the difference between a sufficiency and a shortage for military needs. Further than this, more steel is actually being used than necessary; in fact, more materials of all kinds are being employed than are required for the jobs we wish to do. Better understanding of materials on the part of those responsible for their application would do much to alleviate these shortages.

Through elastic theory (Reference 1)*, photoelastic analysis (2, 3), etc., the designer is well equipped for stress analysis. But of what value is this knowledge if he is unaware of the possibilities and limitations of available materials or of

Fig. 1—Top of page—Tensile test specimens show typical fractures for both ductile and hardened steels

* References are listed at end of article.

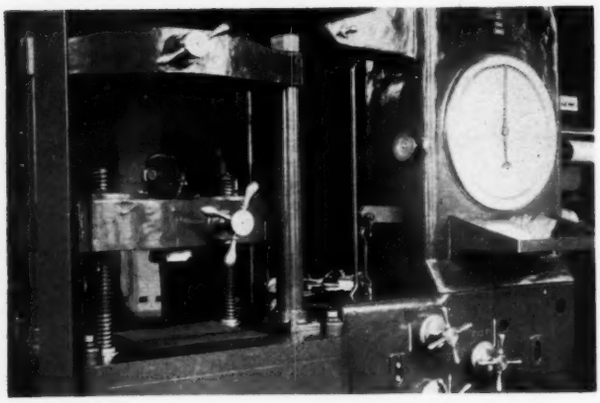


Fig. 2—Hydraulic machine for tension testing strip steel

how they may be developed through suitable heat treatment? The metallurgist cannot completely fill this need because he, in turn, knows too little of the problems of design. Someone must know enough of both fields to co-ordinate their work.

The primary consideration in selecting a material is the prevention of failure. Secondary are workability, cost, availability, etc. It is therefore essential first to consider how parts may fail.

Structurally, a part fails when it becomes dimensionally unsuitable for the service for which it is intended. This may be due to an overstress condition, wear, corrosion or other types of deterioration. Stress failures may be caused by the application of a load of such magnitude as to cause fracture; to result in plastic yielding of some portion so that when the load is removed the original shape is not completely regained; to yield continually at an excessive rate, termed "creep" (4, 5, 6); or last, to develop a "fatigue" fracture (7) from continual repetition of the load.

The only really conclusive test to evaluate the characteristics of a material to the end that such failures may be prevented is service in the field. Lacking this, complete units sometimes may be tested under simulated field conditions. An interesting example is the redesign of the Cadillac transmission, reported by Rothrock (8). For obvious economical reasons, however, the use of such tests is limited. Instead, parts are usually designed by analyzing the stresses and measuring the material by one or more of a number of physical tests.

Tests may be divided into two broad groups—functional and control. From the first are evaluated characteristics considered important to the welfare of the part; from the second the material is controlled to obtain a product which is expected to have the desired physical characteristics.

The habit of placing reliance upon the results of these control tests has become so ingrown that many engineers have come to look upon them as the end to be obtained. These men forget that the results, or qualities, have been arbitrarily set up in the belief that they will give what is really needed. Impact of the war has made substitution all important, however, and the engineer with such a viewpoint is doomed to defeat in his search for a satisfactory substitute because he is seeking qualities he does not need.

A word of caution on the other side. There is an extreme attitude extant among some who advocate physical specifications only. This would be excellent if functional tests were comprehensive. Unfortunately they are not. There are still qualities needed in materials which defy definition, let alone test. Therefore, it is necessary to include control specifications.

Probably the first functional test made was the simple pull test. It was easy to pull the material apart to see what load it would carry; that is, to determine its ultimate strength. From this beginning has developed the modern tensile test, with the wealth of information that it affords (9, 10 and 11).

BECAUSE of the urgent need for every designer to review his steel specifications in the light of the war emergency and limitations on critical and strategic alloying elements, the authors have prepared a series of articles on the subject of which this is the first. Part I touches on the problems of today and briefly reviews the significance of physical tests. Succeeding articles will cover metallurgical aspects, emphasizing heat treatment and the extended uses of carbon steels to relieve the pressure on alloys

In *Fig.* 1 are standard cylindrical test specimens as used for bar and structural shapes. In the foreground is shown a specimen for plate steel. *Fig.* 2 illustrates a modern hydraulic machine designed for testing strip specimens.

The curve, *Fig.* 3, is that for a tensile test typical of an annealed steel. The stress is computed as the total load carried by the specimen divided by the original cross-sectional area between the gage points, not the necked down area. The strain is the percentage change in length over the entire gage distance.

The curve starts on a straight line where the strain is proportional to the stress. The slope (stress divided by strain) is the tensile elastic modulus or modulus of elasticity, approximately the same for all steels and for all conditions of heat treatment. Point *A*, where the curve deviates from the straight line, is known as the "proportional limit". Beyond this the strain is no longer propor-

tional to the stress. Location of this point depends a good deal on the sensitivity of the testing machine—the more sensitive the machine, the lower the proportional limit (12 and 13). In fact, there is reason to feel that a sufficiently sensitive machine would show Hooke's Law not strictly true at any point.

The "elastic limit" is at point *B*. Release of a higher stress will not permit a complete recovery of the strain. In practical testing it is not feasible to release the stress completely, therefore the determination of this point is not readily made. However, this is the value usually desired for design.

At *C* is the "yield point". Here, momentarily, strain continues without increase in stress. This is the point where the beam of the testing machine drops. In the case of the mild steel illustrated by this figure it is easily determined. Since the stress values of elastic limit, yield point and proportional limit are not far apart, it is sufficiently close for commercial work to use the three values interchangeably. The "lower yield point", shown at *D* will not appear in any except carefully made tests. The proportional limit, yield point, etc. are accepted as substitutes to satisfy the requirements of testing.

To examine the curve further it is necessary to

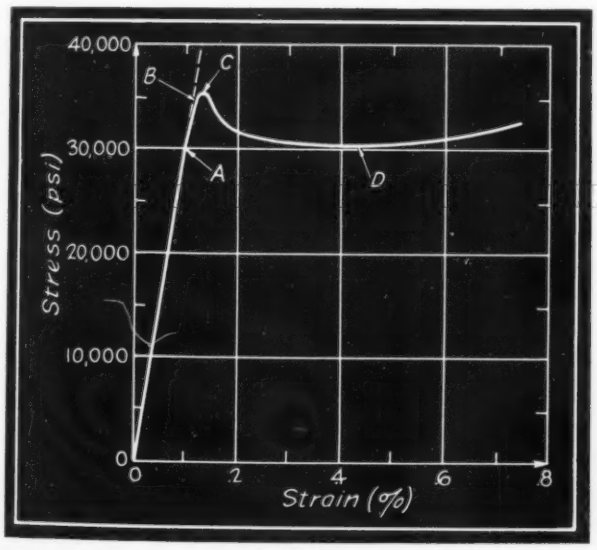


Fig. 3—Typical curve for tension test of soft steel. Strain scale is large to show clearly the elastic portion of the curve

plot with a smaller strain scale, as in *Fig.* 4. The stress value at *E* is the "ultimate strength", indicating the maximum load that the testpiece will carry. If the stress were computed on the reduced area it would continue to increase, giving the so-called "true stress" curve. For a discussion of this and other elements of the strength features of the tension test References 11 and 14 are recommended.

Total strain or "elongation" is indicated in *Fig.* 4. It is usually measured on the fractured specimen, giving actually the plastic strain. As can be seen, the error is negligible. The reduced area is measured at the necked down portion, *Fig.* 1, and the "reduction in area" is the difference between this and the original area. It is expressed in percentage of original area.

Illustrated in *Fig.* 5 is a test curve typical of a heat-treated steel. The yield point is not pronounced, so "yield strength" is commonly used. This is the point where the curve is offset an arbitrary amount *a* from the straight line of proportionality. As defined by A.S.T.M. (9) this term is actually more embracing than the foregoing definition.

Elongation and reduction of area are valuable indications of plastic action. Significance has been attached to them, however, that is not justified by facts. This has unnecessarily increased material costs and is today needlessly slowing up production. After all, except where plastically forming in manufacturing operations, there are few places where the stress will materially exceed the elastic limit. Few structures can stand even 1 per cent elongation. Then why should such high values be demanded? Obviously, it must be with the thought that it guarantees something else in the steel—toughness, stress adjustment, the ability to take it.

Even if it were true that these plastic values tell something of the above qualities, it is surely true that they do not give a quantitative indication. Therefore it cannot be said that one material is better than another because it has a higher elongation figure. The most that is justified is a minimum figure, and this minimum is far below that set by the usual specification. An example is the Ford crankshaft alloy with a reported 2¾

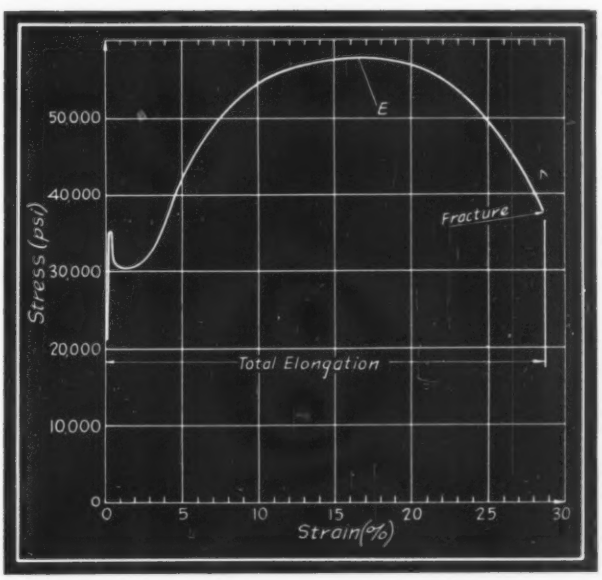


Fig. 4—Tension test shown in Fig. 3 plotted on a smaller strain scale to bring out the plastic portion of curve

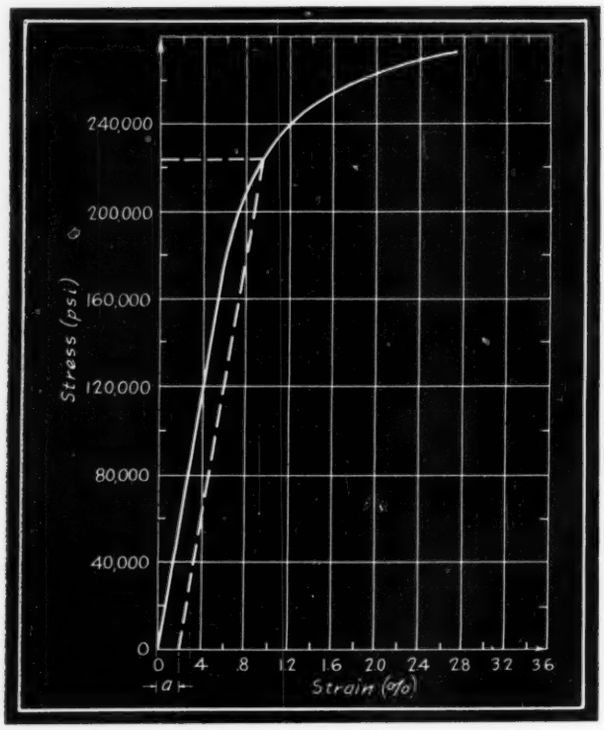


Fig. 5—Tension test curve for a heat-treated steel showing yield strength by the tangent offset method

per cent elongation, 2¼ per cent reduction (15)! Yet it works. The comments of Moore (13) and Gillett (16) on this subject are interesting.

One more point regarding elongation. While the bulk of it is concentrated close to the point of fracture, an appreciable part is distributed over the gage length, particularly in soft steels. This is due to "strain hardening". Deformation at one point along the length strengthens that point, shifting the deformation to the next weak spot. In harder steels, there being little of this strain hardening, the deformation is more localized. Partly for this reason, then, the harder steels show a lower elongation than do the softer ones. It is entirely possible that any small increment of length along the hard steel is capable of almost as great a plastic deformation as in the soft; but the elongation, averaged over the gage length, is less because there are not as many increments that are yielding. In many cases this strain hardening is a desirable feature, but in most cases it is the ability to deform locally rather than the ability to distribute this deformation that is desired. It is the ability to yield, without fracture, at the points of high concentration, that is the needed saving grace. This thought should be kept in mind when considering elongation figures on hard steels.

A variety of other stress tests are useful, such as compression (9), shear and bending tests, etc. (17), torsion (18), and so on. The thought in such tests is that they give the remaining data needed for design. However, actual parts are usually not in any of these simple states of stress. This leads then to an inquiry into failure under combined stresses. That is, what is the effect of stresses in other directions upon the failure stress? This subject is too extensive to permit of treatment in a brief paragraph, therefore the following are recommended: Reference 19 by the writer, the references appended thereto, and the discussions by Gensamer (20 and 26).

There are various "practical" elongation tests which consist of bending samples flat on themselves or around pins, "cupping", forming, etc. They are designed to suit certain materials or special products and vary widely.

Speed of testing has an appreciable effect on the results. Yield and elongation, in particular, may be increased considerably by increase in speed. Permissible testing speed is covered by the A.S.T.M. specifications. In general, larger size specimens are apt to give lower values. Variations, within the limits of ordinary room temperatures, have little effect on the values of tension tests.

Hardness tests have been widely used by the heat treater, partly because of their indication of wear resistance, but primarily as a means of control. Through these he assures uniformity as indicated by the various strength and ductility tests. In addition, tests for hardness are easily and rapidly made and do not require the destruction of any material. Because of their universal use the designer should be thoroughly familiar with them.

Webster defines hardness as "that property of solids . . . . which is indicated by their solidity

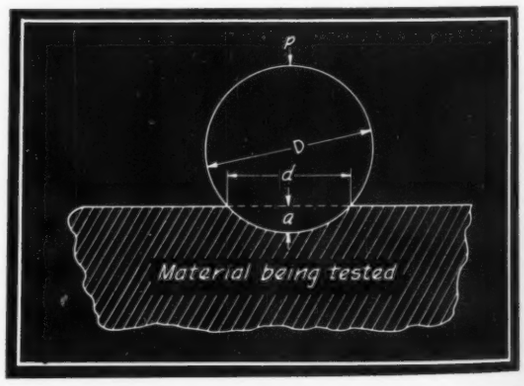


Fig. 6—Indentation made by brinell test ball showing P, the test load; d, the diameter of impression; D, the diameter of the test ball; and a, the depth of impression

and firmness". While this definition leaves much to be desired, we are at a loss to improve on it. This uncertainty is due to the fact that, as may be implied from the definition, each test measures some unknown, complex combination of qualities.

The Shore scleroscope is the best recognized among the impact type of hardness testers. The rebound of a weighted diamond point from the surface under test is the measure of hardness. Rebound is read against an arbitrarily graduated scale, 100 indicating very hardest quenched steels,

and zero no rebound. Because of the difficulty of obtaining reproducible results, application is usually limited to large articles that cannot conveniently be placed within the gap of the various static indentation testers. A full description of the test is included in Reference 21.

The brinell instrument, introduced about 1900, is the earliest form of the static indentation type of hardness tester. Its use remains unsupplanted for many purposes, particularly for tests on rough surfaces of forgings and castings. In the indentation test a hard point is pressed into the material and either the penetration for a given load or the load for a given penetration is measured.

The brinell hardness number is the load divided by the spherical area of the indendation, that is $P/\pi Da$, as indicated in *Fig.* 6. A microscope is used to measure d, the diameter of the impression. The value a is then obtained by $\frac{1}{2}D - \frac{1}{2}(D^2 - d^2)^{\frac{1}{2}}$. Inasmuch as the ball deforms somewhat under load and the impression is also not a perfect sphere, it is necessary to standardize the load, ball diameter and instrument—see Reference 21 and ASTM E10-27 (9)—and to use the above expression for a.

In view of complex qualities involved in this test it is surprising to find that there is a fairly close relationship between the ultimate strength and the brinell hardness number. Approximately, on steels, the ultimate strength is equal to 490 times the brinell number.

The rockwell tester follows the same basic principle as the brinell, except that the *difference in penetration* between an initial (minor) load and a final (major) load is measured. The penetrator is connected to a dial indicator to read the penetration directly. The indicator is set at zero with the minor load in place. The major load is then applied, held for a definite time and then removed, the minor load still being on the point. The penetrator will not recover to its minor position by the amount of the plastic deformation. The dial indicator is arbitrarily graduated to read "hardness numbers".

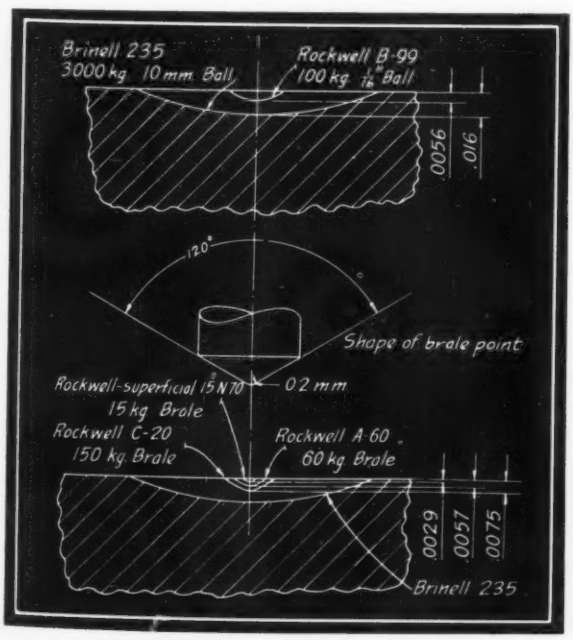


Fig. 7—Size of impressions of a number of penetration tests made on a block of uniform hardness. Scale is 8 diameters to show relative size impressions

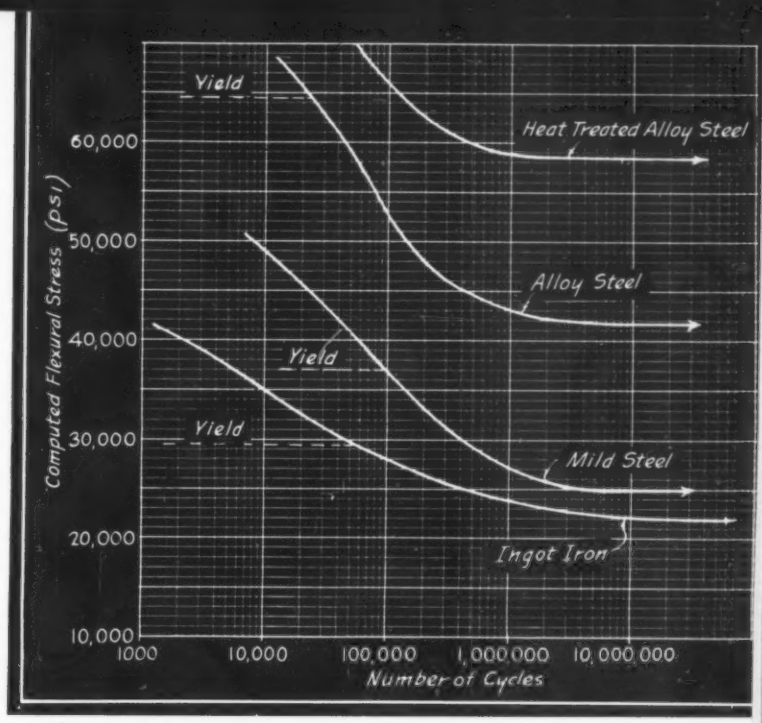


Fig. 8—Typical S-N curves from rotating beam tests

Material Determines Scale Used

The standard rockwell uses a 10-kilogram minor load. By a combination of penetrators and major loads a number of scales is obtained, the different scales being indicated by prefixing a letter to the hardness number. Two scales are recognized as standard. The *C* scale, for hard materials, uses a 150-kilogram major load and a cone-shaped diamond, *Fig.* 7 termed the brale. For soft materials the *B* scale is commonly used. It employs a 1/16-inch diameter ball and a 100-kilogram load. For checking thin or thinly cased steels, an *A* scale, using the brale and a 60-kilogram load, is preferred to avoid breaking through the case or affecting the penetration by the support afforded the material by the anvil. ASTM E18-36 (9) gives a description of the standardized test and Reference 21 a further discussion.

The rockwell superficial tester is used for nitrided or thinly carburized cases, very thin material, pieces where large indentations would be objectionable, etc. The construction is the same as the standard rockwell except for the use of very light minor (3 kilogram) and major loads, and a more sensitive depth-measuring device. This instrument requires considerable skill to operate and care in the preparation of the surfaces to be tested (9).

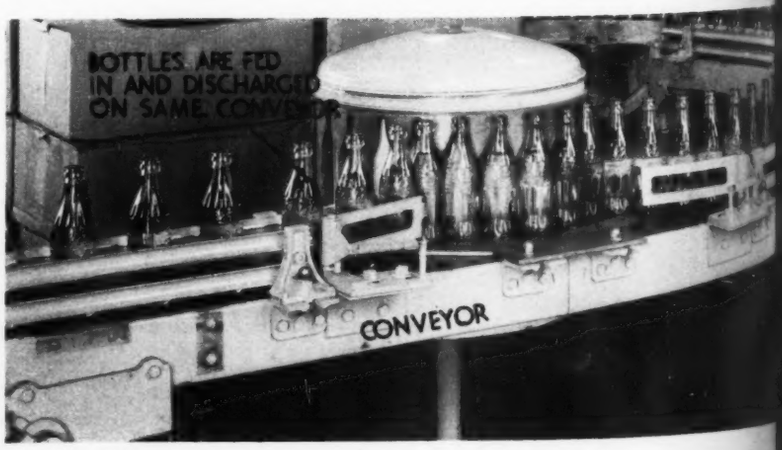
No discussion of hardness is complete without reference to the file test. As usually made, a few

(*Continued on Page* 148)

Scanning the Field for

Blackout of light in interspaces greatly facilitates inspection of bottled beverages as illustrated at right. Today when operator fatigue must be reduced to a minimum, every economical device should be employed to utilize manpower effectively. Previous inspection stations utilizing flooded illumination from the rear had one common fault even though milk or frosted glass were interposed between the lamp and bottles. They allowed too much direct light to strike the operator's eyes, causing straining and making inspection less efficient.

The device shown is connected into the conveyor line of filled bottles. No additional motive power is required because revolving screen is turned by the moving bottles engaging the openings in the screen. An adjustable guide plate engages the bottoms of the bottles and guides them into the screen openings, holding them in contact with the screen. Width of the openings is less than the diameters of the bottles so that they cannot be pushed through. Being a black, light-absorbing phenolic plastic, the screen is ideally suited to the application and will not mar the bottles. Each spade-shaped segment is individually mounted so it may be replaced if damaged. Fluorescent lamps are set closely behind the bottles for efficient lighting and to reduce stray light. Inspection at the rate of 100 a minute can be effectively carried out. Inspection of empty bottles for cleanliness is also aided by this method of lighting.

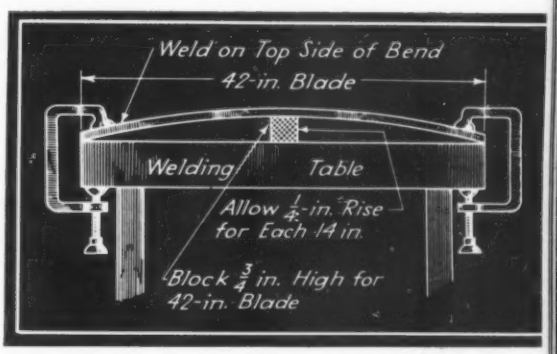


Metallic separation employing the electrostatic principle has been developed experimentally by Westinghouse for separating metal ores containing tin or other war metals from low grade deposits. Promis-

ing results have been attained with a low grade sample from a recently developed tin deposit in a southern state. This sample contained one per cent tin and yielded a concentration of ore containing about 70 per cent tin which is suitable for smelting.

Shown at left, the separator has a foot-wide metal drum which when revolved at a surface speed of twelve miles an hour is capable of segregating ten pounds of ore in one minute. Acting like a magnet the unit can separate dry mixtures of any two materials provided one is a fair insulator and the other has appreciable conductivity. Ground to the fineness of sand, the mixture falls onto the rotating drum. Receiving a high voltage charge from a series of fine wires as the particles fall on the drum, those having conductivity impart their charge to the drum and fall off before the drum has made one-half a revolution. The others cling to the drum until pulled off by a series of charged wires. Separation is shown in the foreground.

Preventing distortion of hard-faced parts is always a problem that must be faced by the designer. Although a production procedure, the method shown schematically below for compensating for distortion is a simple means recommended by The Linde Air Products Co. A scraper blade for cleaning rolls in flour-mill machinery, the part is hard faced on the edge to prevent excessive wear. To overcome the tendency toward bowing, the blade is clamped as shown with a block that is removed immediately after welding. Then, on cooling, the blade returns to its flat position. For this 3/8-inch thick blade, the height of curvature is 1/4-inch for 14 inches of length.



Seamless steel tubing is now being processed into propeller blades by the American Propeller Corp. for army bombers. This process of making hollow blades out of one piece of tubing is highly adaptable to mass production methods and promises to prove better, cheaper and faster than other methods. Formed steel tubing also is highly useful in fabricating structural parts, especially where high strength-weight ratios are needed.

The process consists of a series of hot forging, cold pressing, machining and welding operations. Progressive steps are illustrated at left, including the tubing as received from the mills shown at the bottom to the finished propeller at the top. Intermediate steps include: Precision honed and ground; swaged, upset and polished; bent and flattened; and formed and welded, respectively. In large sizes these blades of chromium-molybdenum alloy are lighter than aluminum, have a greater resistance to corrosion and abrasion as well as better physical properties. Left to right inspecting the display are W. F. Wise, president of the company; Brigadier General A. W. Vanaman, commanding officer of Wright Field; and Brigadier General K. B. Wolfe, chief of production of the U. S. Army Air Forces.

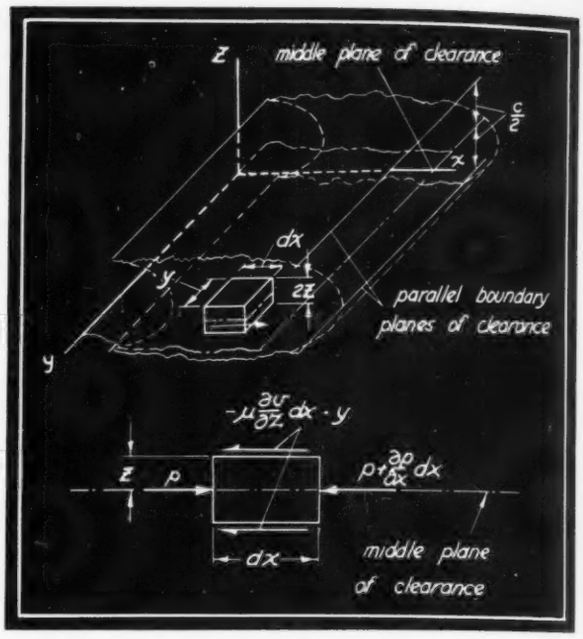


Fig. 1—Leakage flow parallel to the x-axis is found from analysis of small liquid block

By Christian E. Grosser
Mass. Institute of Technology

Hydraulic Leakage Can Be Controlled

HIGHEST efficiency of hydraulically operated machines can be attained only by close attention to details that influence leakage. Costly manufacturing methods used to secure the accuracy now deemed necessary are a handicap to more widespread commercial adoption of hydraulic machinery. As knowledge of the nature of leakage is extended, improved design resulting therefrom will make possible increased production and lower costs. Factors which influence leakage will be discussed in this article from practical and theoretical standpoints, and significant conclusions drawn with respect to their relative importance in leakage control.

The expression

$$\eta_v = 1 - \frac{Q_L}{N_p D_p S_p} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where η_v = the volumetric efficiency of a hydraulic system, Q_L = total volume rate of system leakage flow, N_p = pump speed, D_p = pump displacement per revolution at maximum stroke, and S_p = pump stroke expressed as fraction of maximum stroke, shows conveniently how leakage enters the efficiency picture with respect to hydraulically operated machines. It applies to all positive displacement systems irrespective of type, and may be employed to illustrate important general principles which the designer must recognize in order to minimize the effects of leakage.

The units in which the quantities of Equation 1 are expressed are immaterial as long as the fraction $Q_L/N_pD_pS_p$ reduces to a nondimensional form (pure number). For example, if the total leakage rate of a system be 20 cubic inches per second, the pump speed 30 revolutions per second, the pump displacement 10 cubic inches per revolution, and the pump stroke ½-maximum, the volumetric efficiency becomes $\eta_v = 1 - 20$ in.^{3} sec.$^{-1}$/(30 rev. sec.$^{-1}$ x 10 in.^{3} rev.$^{-1}$ x .5) = .867 or 86.7 per cent.

In the first place the quantity Q_L which is a flow rate of the working fluid either as external or internal leakage from the high pressure region to low pressure (usually near atmospheric) is not affected by any operating conditions other than the pressures and temperatures of the liquid.

Pressure, as will be shown later, theoretically affects the leakage in a linear relationship. That is to say, the leakage rate and pressure fall are always proportional for a given leakage path so long as temperature is constant. Actually the leakage increases somewhat more rapidly than the pressure, because pressure increases are generally accompanied by machine part deflections due to the greater forces imposed. These deflections most often open clearances and therefore have a secondary effect on the leakage flow.

Oprating temperature variations affect the leakage by changing liquid viscosity and also by causing changes in mechanical clearances due to nonuniform temperature distributions through the machine or to unequal expansion coefficients of adjacent parts.

For any given combination of temperature and operating pressures it is possible from examination of Equation 1 to evaluate the effect of the leakage Q_L on the volumetric efficiency under vari-

ous conditions, and hence on the overall efficiency since the latter may be expressed as the product of three factors:

$$\eta_{overall} = \eta_v \times \eta_T \times \eta_e$$

where η_v = volumetric efficiency as before (which measures only the effects of leakage), η_T = torque efficiency (which reflects only the effects of mechanical and fluid friction), and η_e = elastic efficiency (which gives the proportion of recovered stored energy of elasticity, as a portion of hydraulic system descends from high to low pressure).

While it is not within the scope of this article to include a detailed discussion of the latter two efficiency factors, it may be said that they are relatively unimportant in almost all current designs of hydraulic transmissions. However, η_v, because of its sensitivity to certain conditions now to be discussed, may become important enough in the whole efficiency picture to be the determining factor in the success of many hydraulic applications.

Referring again to Equation 1 it will be noted the denominator of the term $Q_L/N_pD_pS_p$ simply represents the delivery flow rate of the variable displacement supply pump. (If the pump is of the "constant" type, S_p is 1). Let it be assumed that the leakage rate Q_L is determined at a given temperature and pressure for a complete system such as a transmission. The determination of this total leakage rate may be by direct measurement on an existing machine, or by calculation according to methods to be described later, by which prediction may be made of probable leakage of a proposed design or of a machine on which measurements may not be conveniently taken.

It is plain that the leakage rate Q_L cannot be greater than the delivery of the supply pump, $N_pD_pS_p$, because then η_v would become negative which is impossible unless another element of the system behaves as an auxiliary supply pump (as for example when a fluid motor which has been overcome by its load is being turned backward).

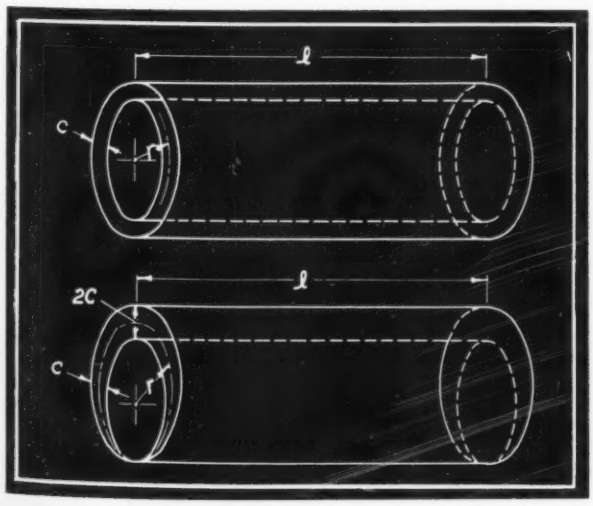


Fig. 2—Upper diagram shows concentric piston clearance, lower shows fully eccentric piston clearance

Volumetric efficiency is obviously highest when the ratio of Q_L to $N_pD_pS_p$ is small. The common approach in designing for high volumetric efficiency restricts itself to considerations for reducing Q_L only. While Q_L must certainly be kept to a minimum, this approach alone ignores the possibilities of further helping matters by considering the pump delivery $N_pD_pS_p$ and how it may be made large compared to Q_L.

First of all the speed N_p should be raised to the highest value possible. This is often ignored by hydraulic designers and consequently much machinery is seen operating at lower efficiency than that of which it is capable. Increase of operating speed is doubly effective since a higher speed permits transmission of power at lower operating pressures and consequently Q_L is reduced. This further increases the volumetric efficiency since not only is the denominator of $Q_L/N_pD_pS_p$ increased, but the numerator is decreased simultaneously. The same effect may be viewed from the standpoint that a higher speed permits small machinery to carry a given amount of power. Smaller units are inherently less leaky since their clearances are smaller. It is therefore axiomatic to operate hydraulic machinery at the highest speeds possible, and thereby, in the words of the practical man, "run away from the leakage." The importance of research and development in the direction of higher operating speeds cannot be overemphasized.

Large Units Have High Leakage

Considering Equation 1 further, D_p cannot be increased to improve the volumetric efficiency since a larger displacement unit has an inherently higher leakage rate because of its larger clearances (the increase in leakage Q_L is nearly proportional to the increase in displacement per revolution D_p). Furthermore, the larger units have a naturally lower operating speed N_p and therefore an increase in unit size should be avoided, and every effort made to operate with the smallest units possible.

The remaining factor S_p, the pump stroke, must be kept large in order to hold up the volumetric efficiency. Therefore, a variable displacement pump operating at partial stroke is to be avoided wherever practicable.

Of course, partial stroke pump operation is part of normal hydraulic transmission operation, and while desirably kept to a minimum certain standards of efficiency must often be met with pump operation at fractional stroke. The only recourse then to offset the damaging effect of a low stroke S_p is in high speed and low basic leakage rate Q_L.

How serious the matter of volumetric efficiency may become is best illustrated by an example. Suppose a transmission system to have a leakage rate at rated pressure of 10 per cent of the maximum pump rate. If the pump stroke be reduced to 10 per cent, the transmission efficiency becomes zero! The

system is thus useless for power transmission at ratios approaching 10:1 and will be very inefficient at other ratios near 10:1.

Great efforts have been exerted by hydraulic equipment manufacturers to reduce leakage by reducing clearances about working parts such as pump and valve pistons and at other sealing surfaces. Working clearances have in many cases been reduced to the order of a few ten-thousandths of an inch, by careful finishing and selective assembly. The results are obtained, naturally, only at great cost, and in consequence hydraulic equipment is excessively expensive. This is one of the chief handicaps to more widespread adoption in commercial applications.

It is interesting and instructive to inquire into the theoretical nature of viscous leakage as it occurs in positive displacement machinery. Particularly is this true for the designer of hydraulic equipment since not only may his pumps, motors and valves be more intelligently designed toward higher operational efficiency, but also costs of manufacture may be lowered by relinquishing practices now considered essential.

The simplest case of viscous leakage is that of laminar flow between two flat plates of uniform length, with planes oriented parallel to each other as in *Fig.* 1.

Analysis Evaluates Leakage Factors

If these plates have a length l in the x-direction of fluid flow, and a difference in pressure Δp between the pressures applied to the two ends of the clearance, we may consider what forces act on a portion of the liquid inside the clearance. It will be assumed that the plates have an infinite extent, or width, in the y-direction at right angles to the flow, so that no edge effects need be considered. By symmetry, a liquid particle should be unaffected by its disposition in the y-direction, and we may therefore assume that the portion of liquid to be studied is located anywhere along the width of the film.

As will become plain it is more convenient to choose a portion of the liquid located halfway between the boundary plates, and having a thickness $2z$ where z is the distance measured from the midplane of the clearance.

Now if an arbitrary location be assumed for the liquid portion in the x or flow direction it will soon develop that this makes no difference. At all points in the direction of flow the average velocity of an isolated portion of fluid equidistant from the boundary planes will be constant. The liquid portion is therefore in equilibrium and the sum of forces acting on it must vanish. Since the forces acting are dependent on the velocity, which does not vary in the direction of flow, the forces must be the same regardless of position in the direction of flow.

Equating to zero the forces acting on a liquid block $y\ 2z\ dz$ as in *Fig.* 1,

$$p2zv - \left(p - \frac{\partial p}{\partial x}dx\right) 2zv + 2\mu\frac{\partial v}{\partial z}dx\ v = 0 \qquad (2)$$

where μ is the absolute viscosity of the liquid and v the velocity at any level z from the midplane.

Simplifying Equation 2 yields

$$z\frac{\partial p}{\partial x} = -\mu\frac{\partial v}{\partial z} \qquad (3)$$

Integrating with respect to z (p assumed constant in the direction z),

$$v = -\frac{1}{\mu}\frac{z^2}{2}\frac{dp}{dx} + C_1 \qquad (4)$$

and from the conditions that the velocity is zero at the boundary plates $z = \pm c/2$, and the velocity is unaffected by changes in the x-direction,

$$C_1 = \frac{c^2}{8\mu}\frac{dp}{dx} \qquad (5)$$

$$\text{and}\quad v = -\frac{1}{2\mu}\frac{dp}{dx}\left(\frac{c^2}{4} - z^2\right) \qquad (6)$$

The velocity therefore varies parabolically between the plates and the maximum occurs at the center, $z = 0$,

$$v_{max.} = -\frac{c^2}{8\mu}\frac{dp}{dx} \qquad (7)$$

where dp/dx is the pressure gradient in the x-direction, which is a constant. In other words the pressure falls linearly from one end of the clearance to the other.

The rate of leakage flow through a width y of clearance will be the average velocity (2/3 of the maximum in a parabolic distribution) taken over the cross section area of the clearance

$$Q = -\frac{2}{3}\frac{c^2}{8\mu}\frac{dp}{dx}c\,y = -\frac{c^3}{12\mu}\frac{dp}{dx}y \qquad (8)$$

or in terms of a total pressure drop Δp along a clearance length l, having a width w

$$Q = -\frac{1}{12}\frac{c^3\,\Delta p\ w}{\mu l} \qquad (9)$$

This is the same formula as given in "Designing for Hydraulic Variable Speed" in MACHINE DESIGN, September, 1941, except that units in Equation 9 are absolute whereas the former was set up for ease of application in engineering units, and in terms of kinematic viscosity (more commonly measured) in place of the absolute viscosity μ above.

In *Fig.* 2 is shown a concentric piston clearance to which Equation 9 may be directly applied since it is exactly the same as the one-dimensional plate case just derived if the ratio of clearance to piston diameter is small.

If the piston is fully eccentric in its cylinder, also shown in *Fig.* 2, integration will show that Equation 9 may be used, but the leakage will be 2.5 times that for the concentric case.

Examination of Equation 9 shows that the mag-

nitude of the clearance c has a most powerful effect on the leakage, since it appears in the equation to the third power.

As illustration of its effect we may, by halving the clearance, reduce the leakage to one-eighth. This is evidence of the profit to be gained by extra care in making seal fits close. On the other hand, while a new piece of equipment may have a low leakage characteristic due to good fits, only a small amount of wear on rigid seal surfaces is sufficient to jump the leakage to several times the original amount, thus rendering the machine inefficient.

The length of seal l and the width w are comparatively insignificant alongside the clearance, since they appear to the first power only. The designer may therefore accept considerable compromise toward wide and short seals, so long as he can be assured of small clearance which may be maintained more or less unchanged throughout the life of the machine.

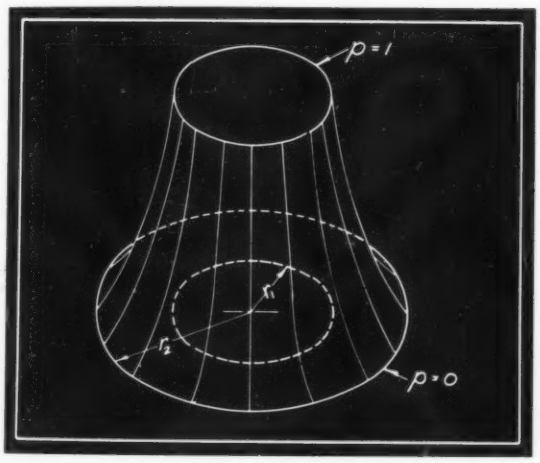


Fig. 3—Distribution of pressure over gasketed pipe flange is logarithmic

This suggests that seals should, wherever possible, be of the piston ring type. These are susceptible to extremely close initial fitting, elastically responsive to pressure differences across them for even tighter fits as pressures rise, and thereby capable of taking up wear as the machine is used. Such rings are short, but their shortness is far more than compensated for by extremely close fits. Their shortness, in fact, is a boon in enabling them to follow such irregularities as may exist in the mating surface.

Rings of leather and elastic plastics of various kinds have been successfully used in a number of hydraulic seals. Experiments are being carried out also at this time on low modulus elastic metals. The effective clearances obtained with such rings, allowing for surface irregularities, are of the order of several hundred-thousandths of an inch. This is to be compared with clearances over the ordinary fitted rigid piston or valve surface, the best practically attainable being of the order of several ten-thousandths of an inch.

Unfortunately the application of pressure-responsive seals has not been carried as far in the manufacture of moderate size piston, gear or vane units, as it has on cylinder cams, shaft closures and pipe fittings. One handicap has been the limitations of space on piston and valve surfaces, a handicap by no means insurmountable. The other is the lack of proper materials to use for seal rings which will stand up under high pressures and high rubbing velocities. Research in this direction is urgently needed, will pay off in greatly improved performance of rotary hydraulic machinery and, because of the feature of automatic clearance take-up rings, should reduce manufacturing costs to a considerable degree by eliminating the extreme close-tolerance surface finishing and selective assemblies so common at present.

The distribution of pressure in the general case of leakage through parallel surface clearances in which the parallel boundary planes have irregular shapes and in which edge effects may not be eliminated, such as in the piston or infinitely long parallel planes of constant width, is described by the differential equation

$$\frac{\partial^2 p}{\partial x^2}+\frac{\partial^2 p}{\partial y^2}=0 \qquad \text{.....(10)}$$

where p is the pressure, and x and y the rectangular co-ordinates in which the leakage region is located.

Equation 10 is extremely difficult to solve for irregular boundary shapes with complicated distributions of pressure at the ends of the clearance. A useful mental picture of pressure distribution in such cases may be obtained through the use of an analogy. Equation 10 also describes the configuration (or relative height) of a constant tension membrane which is stretched between points which have heights proportional to the values of pressure at the boundary edges of the leakage clearance. The tension membrane such as a rubber sheet gives an exact picture only for small deflections; a membrane deflecting in pure shear gives an exact solution of Equation 10 for any magnitude of deflection. *Fig.* 3 thus shows the distribution of pressure over an annular pipe flange seal, the inner edge of which is subjected to the pipe pressure taken as 1 and the outer held to 0. The distribution of pressure over the seal surface is logarithmic. The picture is useful to the designer in making his estimate of the average pressure over the surface to calculate the stresses in flange bolts, etc.

The solution of Equation 10, while difficult to carry out formally by accepted mathematical procedures, may be achieved to a close degree of approximation by a graphical procedure* developed recently.

* "Solution of Partial Differential Equations of the Poisson Type by Graphical Means and by the Use of a Mechanical Analyzer"—C. E. Grosser, M. I. T. Thesis in Mechanical Engineering, 1942.

Which Thermostat?

By John W. Greve

Part I—Bimetals, Pyrometers

AUTOMATIC temperature regulation is the most important function of instruments used in equipment for industries such as oil refinery, food, chemical and plastics. Many war machines depend on thermostatic elements of one type or another for their operation. Liquid-cooled aircraft engines could neither develop maximum horsepower nor high efficiency were it not for temperature controls that automatically compensate for various combinations of atmospheric conditions and power requirements. Typical of industrial applications is the injection molding machine in *Fig.* 1 where two thermostats automatically control injection temperatures as well as indicate them to the operator. Thermal controls have countless other useful and critical functions such as assuring that bearings operate at safe temperatures as illustrated schematically in *Fig.* 2.

Temperature control may be grouped into the following general classes: (1) Indicating; (2) recording; (3) signalling; (4) automatic controlling. Of these groups, 3 and 4 will be discussed specifically as they are affected by various types of temperature-sensitive elements. Upon the proper selection of these elements depends the degree of accuracy obtained from the control.

There are three basic types of control. They are

1. On-off
2. Modulating or proportioning
3. Floating

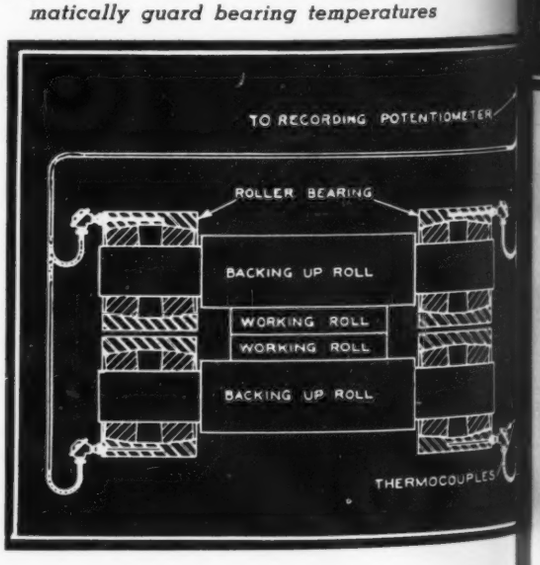
In the first are included operation of air conditioning equipment, safety devices in event of failure of fuel supply, etc. The second embraces those applications involving throttling actions such as coolants for internal combustion engines and regulation in process industries. Floating types are used where it is desired to increase or decrease the controlled elements as the preset value is approached.

Regardless of the type of thermostat employed there is a lag in temperature response. This differential between the medium and element may be due to

1. Position of element in medium
2. Radiation losses
3. Heat capacity of element

Fig. 1—Two automatic thermostats control injection temperatures in a plastics molding press. Indicating instruments show the conditions at all times

Fig. 2 — Below — Thermocouples automatically guard bearing temperatures

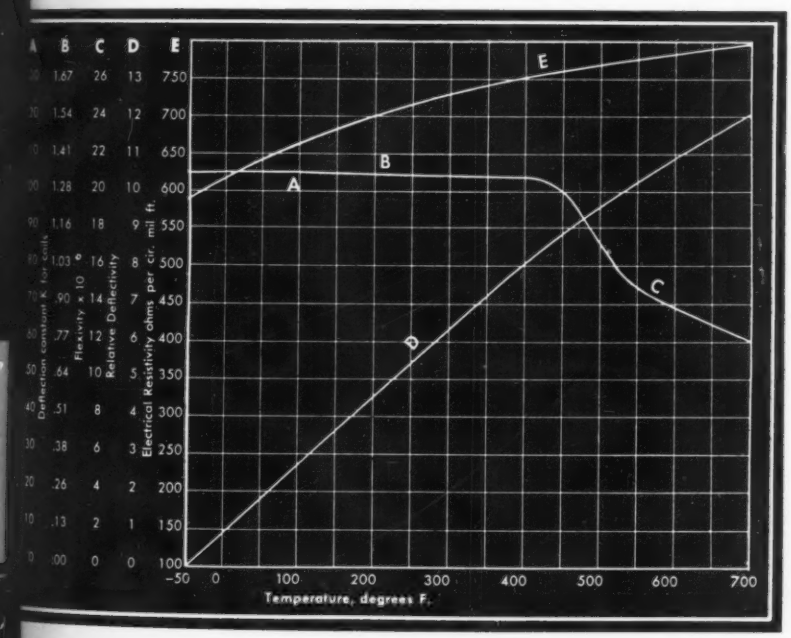


4. Gradient in medium
5. Response of controlling unit
6. Rate at which medium changes temperature.

In the majority of applications, it is not required to ascertain the "true" temperature. Rather, relative changes are desired that are characteristic of the whole and which the designer attempts to attain. Careful specification can minimize undesirable lag and will be discussed more fully with different kinds of control.

Temperature-sensitive elements must have the required physical properties and respond quickly with sufficient force as to be dependable. Following is a classification of the major types of thermo-sensitive units.

1. Metallic
   a. Rod and tube
   b. Bimetal
   c. Single metal (perforated)
2. Pressure bulb
   a. Gas
   b. Vapor pressure
   c. Liquid
   d. Mercury
3. Thermoelectric
4. Resistance thermometer



5. Photoelectric-optical pyrometer
6. Radiation pyrometer

Rod and tube units depend on unequal thermal expansion of the dissimilar metals used for the parts. These often control throttling valves. Being a rigid-couple unit the valve is assembled to the temperature-responsive element, requiring the valve to be so constructed that the heat does not affect it. Considerable force is developed in this type of control, which compensates in a measure for the small expansion available. A brass rod, for instance, expands .0001-inch per foot per degree Fahr. This type of control has a normal operating differential of 5 degrees Fahr. Pivots or other linkages are undesirable because they introduce points of wear, reducing the effective stroke.

Bimetal thermostats, consisting of two metals with widely different rates of thermal expansion bonded together by brazing or welding, are particularly adapted to electrically controlled units. Invar has been the usual thermally active element of most bimetal units, although its temperature range is limited to below 600 degrees Fahr. Development of high-expansive, nickel-chrome steel increased the operating range to 1200 degrees. Bimetal units with different combinations of alloys are applicable down to —50 degrees.

Typical characteristic curves for a bimetal are shown in *Fig.* 3. In applying this type of element the following formulas are helpful in determining the deflection of cantilever strips or coils of either helix or spiral designs.

Deflection:

$$D=\frac{k\,Tl^2}{t}$$

$$A=\frac{kTl}{t}$$

Torque:

$$P_s=\frac{k\,Dbt^3}{l^3}$$

$$P_c=\frac{k\,Abt^3}{lr}$$

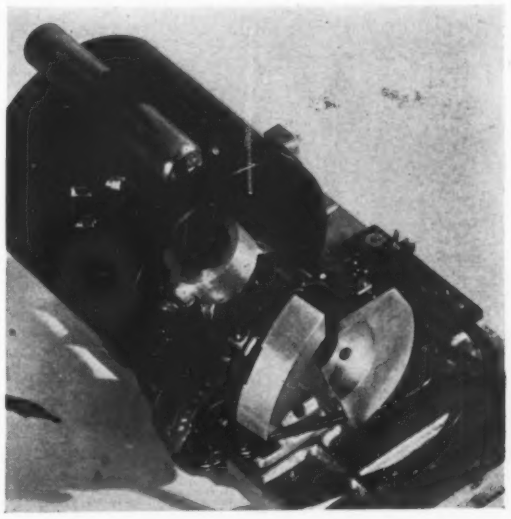
Maximum load:

$$f=\frac{6\times10^6 Pr}{bt^2}$$

where D is the deflection at end of strip (in.);

Fig. 3—Left—Typical characteristics of a bimetal developed for desirable response

Fig. 4—Below—Bimetal disk maintains oil temperature in aircraft motor



A, angular movement (degrees); T, temperature rise (F); l, length of strip (in.); t, thickness of strip (in.); r, radius at point of load (in.); b, width of strip (in.); P, pull (lb. at 80F); f, maximum load (psi); k, deflection constant of bimetal.

Shape and size of the element employed depends on the motion desired, amount of movement and effective force. Line motion is obtained generally with strip, angular with coils of the helix or spiral shape. The helix is desirable when it is necessary to have a large area in contact with the measured medium or when an averaging measurement is needed. Spiral are useful for compact designs when effective measurement is obtainable in a restricted area. The length of the coil determines the amount of motion for a given temperature change.

Additional shapes include U's, hairpins, compound curves, etc., depending on the requirements of the applications. Contacts usually are of the button type, insulated from the bimetal. The bimetal may be used for current carrying when operation is not affected or when its resistance acts as a current-limiting device. Often mercury switches are employed for electrical contacts, especially for the coil types. In this way multiple contacts are obtainable with a single bimetal element by fixing the angular position of each switch to operate at the desired temperature.

If sensitivity is the prime consideration, strip type units are employed provided the current demands are not too high. Where a thermostat must carry a high current or direct current, a quick make-and-break type is needed. Snap action is derived in various ways—dishing, crimping or other methods giving overcenter action. Often a small magnet is employed on the high temperature contact to pull the bimetal quickly when it tends to expand. Also, in this type of unit, a simulated floating action may be obtained with a simple on-off or two-contact unit by the inclusion of a small heater coil in the circuit to hasten the action of the bimetal and prevent overtravel of the control.

Disk type bimetal thermostats have the combined advantages of being compact with the ability to be located closely to a critical temperature. These are snap action and can be calibrated within relatively close limits. They are used for controlling strip heaters and other types of electrical heating units. In addition, when embedded in the frame or windings of a motor, they protect against excessive temperatures and possible failure.

Requiring no magnets, springs or toggles, the disk type has an initial "dish" so that it snaps over center to make or break the control contacts. The amount of dish and the bimetal employed determine the operating temperature. To develop higher forces, thicker bimetals are used. Thicker units have greater thermal lag and slower response.

Controls Engine Oil Temperature

In Fig. 4 is shown a disk type thermostat applied to a motor lubrication problem that is particularly important in the aircraft industry. To combat temperature changes due to varying altitudes the oil temperature must be held constant. The thermostat controls the operation of a cartridge heater.

Vibration introduces problems in insuring that the contacts do not chatter nor change in calibration. The unit shown in *Fig.* 5 is designed to combat these conditions and varies from the conventional by the use of a hex-shaped insert that is spun and riveted into position. In the center is a slotted screw or pin that supports the disk. With this, the final setting of the thermostat is made. To avoid any change from vibration, a hole is drilled in the insert and the pin, and then keyed.

Bimetal thermostats sealed in inert gas have advantages for extremely sensitive and accurate operation. They are strip type units and are so designed that the thermo-sensitive element does not carry current. When not operating, the bimetal is free from the current-carrying parts. As temperature rise causes deflection, the contacts are

Fig. 5—Above—Thermostat developed for use where vibration might affect calibration

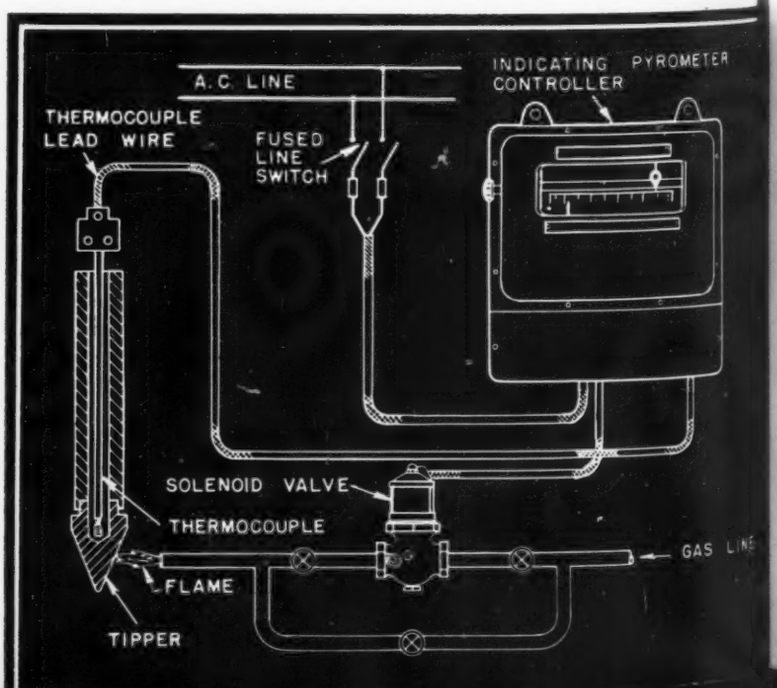


Fig. 6—Right—Compactness of thermocouple and adaptability to accurate control problems make it useful for controlling tipper temperature for soldering cans in automatic filling machine

separated by the bimetal pressing against the movable side. Any stray current passing through the element would then tend to hasten separation. These units are available for both alternating current and direct current and in ratings from ½ to 15 amperes, carrying loads as high as 2000 watts. Calibration tolerances range from ± ½ degree for the smaller sizes to ±5 for the larger, operating on temperature changes from 1/10 to 1 degree.

Chief advantages of bimetal are its simplicity of application, uniformity of action between similar units and over a period of time, and relatively low cost. Principal disadvantage involves those controls where electric energy is not available or relay operation becomes involved or costly, as for instance when motors are needed.

Thermostats employing single metals depend on unequal rates of thermal transfer across the element to obtain deflection. The horseshoe type, for instance, has holes closely spaced toward the inside edge of the bend to restrict the heat transfer. This type has been developed for safety control of pilot gas flames and provides a dependable unit for closing a valve by electric relay. Another interesting unit has a slit in the element and a piece of asbestos interposed to utilize the same principle.

Controls involving high temperatures, high sensitivity, indicating, or recording require other types of thermo-sensitive units. Pyrometers utilizing thermocouples are almost universal for temperature measurement in the range of 1000 to 3000 degrees. They are also widely used in the ranges between —200 and 1000 degrees Fahr. Thermoelectric pyrometers are more expensive than the common thermostat; they are especially suitable for indicating and recording applications used in conjunction with automatic control, *Figs.* 2 and 6. They are competitive with other types employing pressure bulbs filled with gas, vapor-pressure, liquid or mercury. Despite popular conceptions, industrial pyrometers are not extremely delicate—the new electronic type being exceedingly sturdy.

Thermocouple Characteristics

Positive Wire	Negative Wire	Wire Size (in. or B&S)	Operating Temp. (max.) (degrees Fahr.)	E M F* (millivolts)
Platinum	Platinum-Rhodium	.022	2800	18.45
Chromel	Alumel	8	2000	43.94
Iron	Constantan	8	1400	41.70

*Generated electromotive force is based on a cold junction temperature of 75 degrees Fahr.

Thermocouples consist of two dissimilar metals in contact with each other and with their junction placed at the temperature to be measured. Temperature of the medium causes the generation of an electromotive force which is measured on either a millivoltmeter or a potentiometer calibrated in degrees of temperature. Use of a millivoltmeter requires compensation for cold junction and variations in lead wire lengths whereas a potentiometer, being a balanced type instrument, needs only cold-junction compensation. Millivoltmeters are less accurate, simpler and consequently less expensive.

When selecting a thermocouple, a number of factors must be considered such as operating temperature, sensitivity required, life of instrument, and corrosive effects of the medium. By balancing these against the characteristics available, a satisfactory selection can be made. The preceding table lists typical thermocouples with their operating temperatures and generated electromotive forces.

Protecting tubes are usually used even though some sensitivity is sacrificed. They provide longer life and allow higher operating temperatures. If length of life is not as important as high accuracy, smaller wire gage may be used. Reduction of the size of gage, however, lowers the maximum operating temperature and life. Larger wire sizes and tubes also increase the thermal lag of the couple.

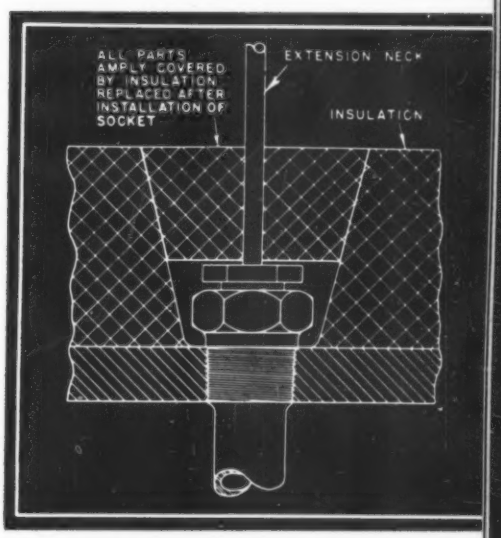
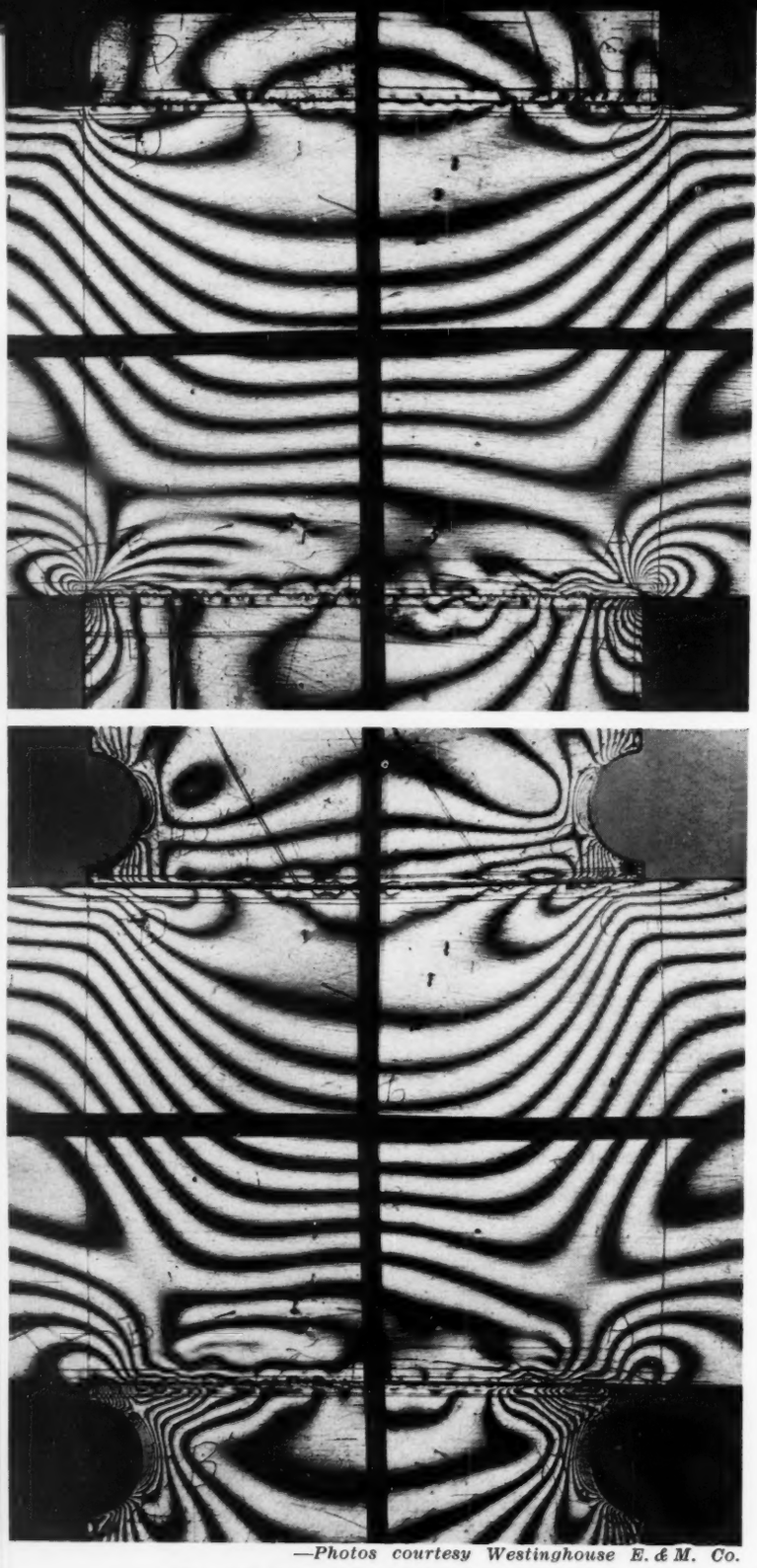


Fig. 7—Recommended method for installing temperature-bulb socket within insulation, having maximum length in the medium

Thermal conductivity of protective tubing is another factor which affects accuracy. Low reading may be caused by a tube with a heavy wall or by insufficient depth of immersion. Because temperature gradients along the tube cause heat to be conducted away from the hot junction, immersion should be such as to minimize this effect. In general at least six inches is required to avoid errors of this type. In keeping with the needs for conservation of materials, it is important to select the minimum sizes of wire and tubing to perform the job required. Overdesign is not only costly and harmful to the war program but also results in a less satisfactory instrument.

Certain thermocouple wires will withstand atmospheric conditions of an application while others will not. Iron-constantan may be used in either oxidizing or reducing atmospheres. The maximum temperature under oxidizing conditions is less than under reducing conditions, however. Because of lower cost it is recommended wherever conditions permit. Chromel-alumel are most satisfactory in slightly oxidizing atmospheres and at elevated

(*Concluded on Page* 162)



—Photos courtesy Westinghouse E. & M. Co.

Fig. 15—Photoelastic stress patterns for ordinary and grooved hubs show how design affects stress concentration for these two types

Fig. 16—Below—Typical fractures of shrink-fit assemblies resulting from fatigue stresses

Designing Sh Fi

By Joseph Marin
Illinois Institute of Technology

IN THE previous sections of this three-part series, design of shrink-fit assemblies was considered when subject to static loads. As an indication of stresses resulting from the fit, *Fig.* 15 shows typical stress-fringe photographs for two types of hubs. In many cases there may be fluctuating or fatigue stresses present and in such instances the previous analysis must be modified. A common type of fluctuating stress is that due to bending in the case of a rotating axle or shaft. These fatigue bending stresses are completely reversed each revolution and the influence of this type of stress on the design of a shrink-fit assembly may be appreciable. In *Fig.* 16 are three fatigue failures, showing characteristic fractures. A theory for combined fatigue stresses is discussed in this article and several types of shrink-fit assemblies subject to different kinds of loads are analyzed. As in other articles of this series, design charts are presented.

Provision for the effect of fluctuating combined stresses on the design of machine members has been made in various ways. Approximate methods and other methods using more recent information on the behavior of metals when subject to combined fatigue stresses have already been reviewed.[1] In this article the theory, developed by the writer, agrees best with the test results available for ductile metals subject to combined stresses. In the preceding reference, only two-dimensional stresses were considered. In shrink-fit assemblies such as a hub and shaft subject to bending, a three-dimensional state of stress exists. For this reason another theory, similar to that used for design of shafting, must be developed. Instead of using the distortion energy as the quantity which governs failure, the total-strain energy will be used. This is due to the inconsistency appearing in the distortion-energy theory for three-dimensional stresses.[2] Using the total-strain energy as a criterion of failure, a theory can be developed giving the relationship between the stress components at failure. A similar theory based on distortion energy has been developed in detail.[3]

[1] See J. Marin—"Designing Shafting for Static or Fatigue Loads", MACHINE DESIGN, August, 1941.

[2] This has been discussed in previous articles of this series where three-dimensional static stresses are considered.

[3] "Working Stresses for Members Subjected to Fluctuating Loads", *Transactions*, A.S.M.E., 1937, Vol. 59, Page 55.

Shrink Fit Assemblies

Part III—Fatigue Stresses

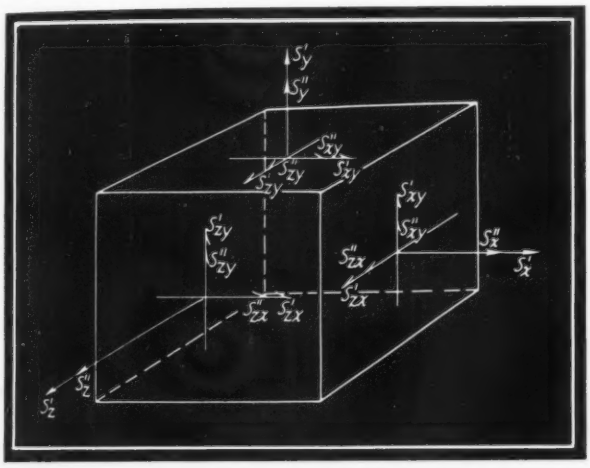
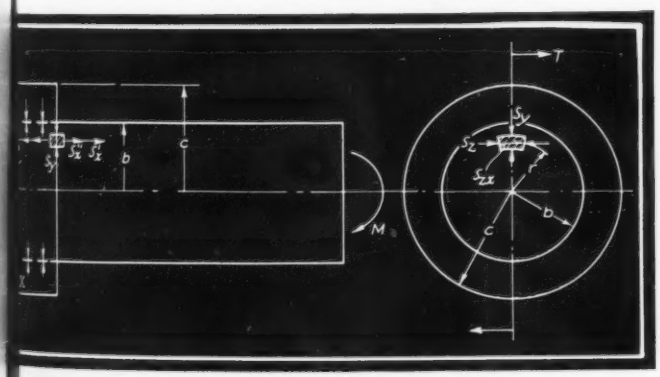


Fig. 17—Element subject to three-dimensional fluctuating stresses, not all present in shrink-fit assemblies

Fig. 18—Below—Stresses in rotating solid hub and shaft subject to bending and twisting



In *Fig.* 17 a stressed element subject to three-dimensional fluctuating stresses is shown. The "prime" normal stresses S'_x, S'_y, S'_z and shearing stresses S'_{xy}, S'_{yz}, S'_{zx}, represent the maximum values of the fluctuating stresses while the remaining "double prime" values represent the mean values of these variable stresses. The maximum values of the stress components will be assumed to be synchronous, that is, they are assumed to occur at the same instant of time. The same condition applies to the mean stress values. Based on the total-strain energy as the stress function governing failure, a theory can be obtained giving the relation of failure between the stress components of *Fig.* 17. This study shows that the stress relation at failure is

$$S_e=\sqrt{(S'_x)^2+(S'_y)^2+(S'_z)^2-2m(S'_xS'_y+S'_yS'_z+S'_xS'_z)+\frac{E}{G}\left[(S'_{xy})^2+(S'_{yz})^2+(S'_{zx})^2\right]}-(1-p)\sqrt{(S''_x)^2+(S''_y)^2+(S''_z)^2-2m(S''_xS''_y+S''_yS''_z+S''_xS''x)+\frac{E}{G}\left[(S''_{xy}{}^2)+(S''_{yz})^2+(S''_{zx})^2\right]} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

where E = modulus of elasticity in simple tension
G = modulus of elasticity in shear
m = Poisson's ratio
S_e = endurance limit for complete reversal
p = an experimental constant = S_e/S_{yp}
S_{yp} = yield strength of material.

Equation 1 can be used for design provided the failure stress is replaced by the allowable stress.

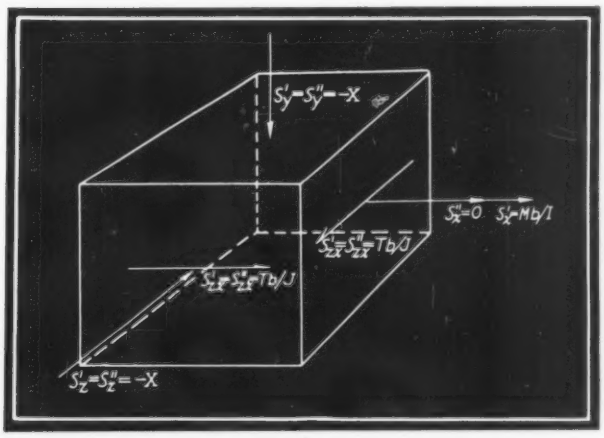


Fig. 19—Stresses in element of Fig. 18

To do this S_w becomes the working stress in simple static tension. Then, if n is the factor of safety,

$$S_w=\frac{S_{yp}}{n}=\frac{S_e}{pn} \quad or \quad S_e=pnS_w \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

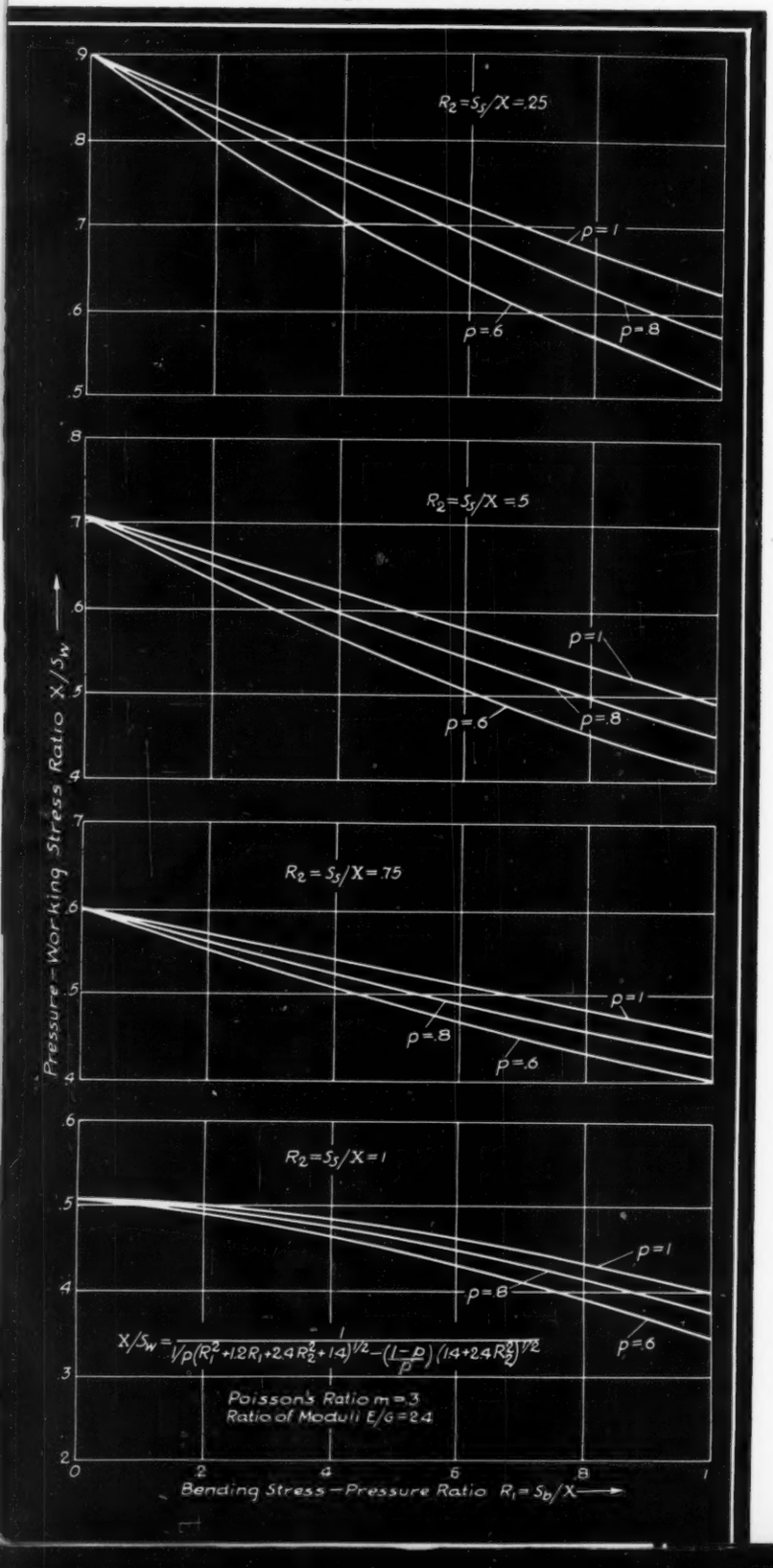
Placing the value of S_e from Equation 2 in Equation 1, the relationship between the allowable values of the stress components becomes

$$S_w=\frac{1}{p}\sqrt{(S'_x)^2+(S'_y)^2+(S'_z)^2-2m(S'_xS'_y+S'_yS'_z+S'_xS'_z)+\frac{E}{G}\left[(S'_{xy})^2+(S'_{yz})^2+(S'_{zx})^2\right]}-\frac{1-p}{p}\sqrt{(S''_x)^2+(S''_y)^2+(S''_z)^2-2m(S''_xS''_y+S''_yS''_z+S''_xS''_z)+\frac{E}{G}\left[(S''_{xy})^2+(S''_{yz})^2+(S''_{zx})^2\right]} \quad (3)$$

In obtaining Equation 3 from Equation 1 it should be noted that the values of the stress components in Equation 1 divided by the factor of safety n are the allowable values of the stresses expressed in Equation 3.

For the shrink-fit assembly, all the twelve stress values shown in *Fig.* 17 fortunately do not exist. For most assemblies it is necessary to consider only the normal stresses and one shearing stress. The following examples will serve as illustrations:

Fig. 20—Charts for selecting allowable bending stress or torque. Ratio of moduli E/G=2.4



EXAMPLE 1—SOLID SHAFT OR AXLE SUBJECT TO SHRINK-FIT STRESSES, STATIC TORSION AND FLUCTUATING BENDING: A rotating, solid hub and shaft assembly subject to bending and twisting moments M and T is represented in *Fig.* 18. Due to the shrink-fit pressure, normal static stresses of magnitude X will be produced, as shown in *Fig.* 19. In addition there is a static torsional stress S_{zx} and a fluctuating bending stress S_x. The other shear stress components will be assumed equal to zero since transverse shear stresses in most problems of this type are negligible. The stresses in terms of loads are

$$\left.\begin{aligned} S'_x &= \pm\frac{Mb}{I}, \qquad S''_x = 0, \qquad S'_{xy} = S''_{xy} = 0 \\ S'_y &= S''_y = -X, \qquad\qquad S'_{yz} = S''_{yz} = 0 \\ S'_z &= S''_z = -X, \qquad\qquad S'_{zz} = S''_{zz} = \frac{Tb}{J} \end{aligned}\right\} \quad ..(4)$$

where b is the radius of the shaft or axle, I the moment of inertia of the section, and J the polar moment of inertia of the section.

Placing the values of the stresses from Equation 4 in Equation 3,

$$\frac{S_w}{X} = \frac{1}{p}\sqrt{\left(\frac{S_b}{X}\right)^2 + 2(1-m) + 4m\left(\frac{S_b}{X}\right) + \frac{E}{G}\left(\frac{S_s}{X}\right)^2} - \frac{1-p}{p}\sqrt{2(1-m)+\frac{E}{G}\left(\frac{S_s}{X}\right)^2} \quad .....(5)$$

where S_b is the bending stress Mb/I, and S_s is the shear stress Tb/J.

Equation 5 can be written more conveniently as

$$\frac{X}{S_w} = \frac{1}{\frac{1}{p}\sqrt{R_1^2+4mR_1+\frac{E}{G}R_2^2+2(1-m)} - \frac{1-p}{p}\sqrt{2(1-m)+\frac{E}{G}R_2^2}} \quad .....(6)$$

where the stress ratios R_1 and R_2 are S_b/X and S_s/X, respectively.

Equation 5 or Equation 6 gives a relationship between the allowable values of the bending and torsional stress for a given shrink-fit pressure. The result can be used in various ways. For example, knowing the shrink-fit pressure and the twisting moment applied to a shrink-fit assembly, the allowable fluctuating bending stress and, hence, the bending moment can be obtained. To aid the designer in selecting a shaft diameter or in determining the allowable torque or moment, the variation between the pressure-working stress ratio, X/S_w, and the bending stress-pressure ratio R_1 is given in *Fig.* 20 for different values of the shear stress-pressure ratio R_2. These graphs are determined by using Equation 6. Values of $E/G=2.4$ and $m=.3$ were used to plot these diagrams—these values being good approximations for most steels and other duc-

tile materials. For the experimental constant $p = S_e/S_{yp}$, a range of values from .6 to 1 is used. These are representative of quantities which are likely to occur.

There are various ways that the design charts in *Fig.* 20 can be used. For example, in a shrink-fit assembly of known shaft diameter and shrink-fit pressure, the pressure-working stress ratio, X/S_w, is known. Then for a given torque and material the appropriate curve can be selected from those given in *Fig.* 20. The coordinate $R_1 = S_b/X$ of a point on this curve corresponding to the known pressure-working stress ratio, X/S_w, can then be selected. This gives the allowable bending stress and, hence, from $S_b = Mb/I$ the allowable fluctuating bending moment can be selected. In a similar manner the diagrams can be used to select the allowable torque or to determine the required shaft diameter. It has previously been mentioned that the shrink-fit pressure X is usually based on standard practice. .

Charts Include Most Values

It should be mentioned that the graphs cover most shrink-fit pressure values but for low values it is simple to plot graphs similar to *Fig.* 20 covering these other possibilities by using values of $1/R_1$ from 0 to 1 in place of R_1 from 0 to 1 as in the plotted diagrams. The designer should also be informed that the diagrams apply for a ratio of the moduli $E/G = 2.4$ and a value of Poisson's ratio $m = .3$. These are good approximations for many ductile materials. In addition it should be realized that curves are plotted for values of the experimental constant $p = S_e/S_{yp}$—the ratio of the endurance limit for complete reversal to the yield strength of the material—representing the usual range of values for this constant. If the values of these experimental constants are not known an estimate can be made by comparing with reported values for a similar material. For a new design or where economy and safety are particularly important, it may be desirable to obtain more accurate test data. It should be realized, however, that although the theory used in this paper has more experimental support than the usual procedure, there are certain assumptions made in formulating this theory.

EXAMPLE 2—SOLID SHAFT SUBJECT TO SHRINK-FIT STRESSES AND FLUCTUATING BENDING: If there is no twisting moment T in the assembly shown in *Fig.* 19, then $R_2 = 0$ in Equation 6 and the pressure-working stress ratio becomes

$$\frac{X}{S_w} = \frac{1}{\frac{1}{p}\sqrt{R_1^2 + 2(1-m) + 4mR_1} - \frac{1-p}{p}\sqrt{2(1-m)}} \quad \ldots (7)$$

The variation between the bending stress-pressure ratio $R_1 = S_b/X$ and the pressure-working stress ratio X/S_w is given in *Fig.* 21. In plotting these variations, representative values for ductile materials for the experimental constants p and m are used. Thus the diagrams are shown for three values of Poisson's ratio m, ranging from .25 to .35. The variation of the experimental constant $p = S_e/S_{yp}$ is selected as in the previous example with a variation from .6 to 1.

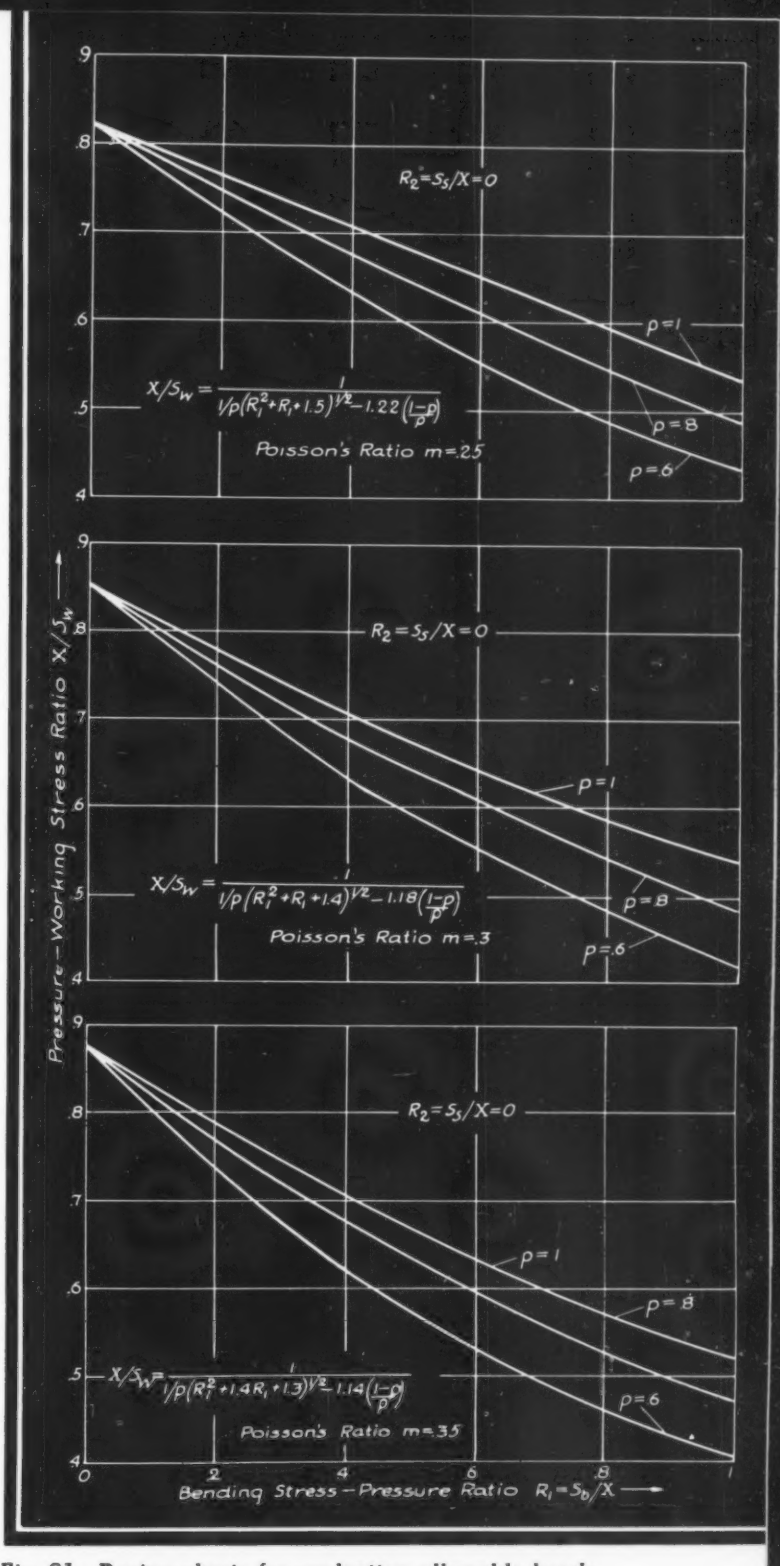

Pressure – Working Stress Ratio X/Sw
Bending Stress – Pressure Ratio R1 = Sb/X
R2 = Ss/X = 0
p = 1
p = .8
p = .6
X/Sw = 1 / 1/p(R1² + R1 + 1.5)^1/2 − 1.22((1−p)/p)
Poisson's Ratio m = .25
X/Sw = 1 / 1/p(R1² + R1 + 1.4)^1/2 − 1.18((1−p)/p)
Poisson's Ratio m = .3
X/Sw = 1 / 1/p(R1² + 1.4R1 + 1.3)^1/2 − 1.14((1−p)/p)
Poisson's Ratio m = .35

Fig. 21—Design charts for evaluating allowable bending moment or shaft diameter. Ratio of moduli E/G = 2.4

The graphs in *Fig.* 21 can be used to determine the allowable bending moment or the shaft diameter. To determine the allowable bending moment it is first necessary to select the values of the constants p and m. This selection determines the curve

to be used. The pressure-working stress ratio, X/S_w, will be known for a particular shaft, since the shrink-fit pressure X is governed by other considerations and since the working stress value S_w selected will be based on the material used and other factors. With the stress ratio X/S_w known, the corresponding coordinate $R_1 = S_b/X$ can be selected. This determines the allowable bending stress and, hence, the bending moment that may be used.

EXAMPLE 3—SOLID SHAFT SUBJECT TO SHRINK-FIT PRESSURE AND A FLUCTUATING AXIAL LOAD: For a shrink-fit assembly subject to fluctuating axial stress, an element as shown in *Figs.* 17 and 18 will be subject only to normal stresses S_x, S_y and S_z. The magnitudes of the maximum and mean values of the stresses for a completely reversed axial load P are

$$\left.\begin{aligned} S'_x &= \pm\frac{P}{A_r}, \qquad S''_x = 0 \\ S'_y &= S''_y = -X \\ S'_z &= S''_z = -X \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots (8)$$

where A_r is the area of the shaft. Placing the values of the stresses from Equations 8 in Equation 3 and noting that the other stress components are zero,

$$\frac{S_w}{X} = \frac{1}{p}\sqrt{R_3^2 + 4mR_3 + 2(1-m)} - \frac{1-p}{p}\sqrt{2(1-m)} \qquad (9)$$

where

$$R_3 = \frac{S'_x}{X} = \frac{P}{A_r X} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

By Equation 9, the variation between the working stress-pressure ratio S_w/X and the axial stress-pressure ratio $R_3 = S'_x/X$ is completely defined for known values of the experimental constants p and m. The variation between these two quantities is represented in *Fig.* 22 for different values of Poisson's ratio m and the experimental constant p. Values of R_3 are plotted in the horizontal direction. Then, by Equation 10 the required area $A_r = (P/X)(1/R_3)$, and the area A_r is, therefore, P/X divided by the coordinate R_3 as shown.

Charts Determine Diameter

The charts in *Fig.* 22 can be used for selecting a shaft or axle diameter. A trial and error procedure, however, must be used since the shrink-fit pressure is dependent upon the diameter. It is first necessary to select the material and to determine or estimate the values of the experimental constants p and m. This selection determines the curve to be used from those that are given in the figures.

The working stress S_w and shrink-fit allowance

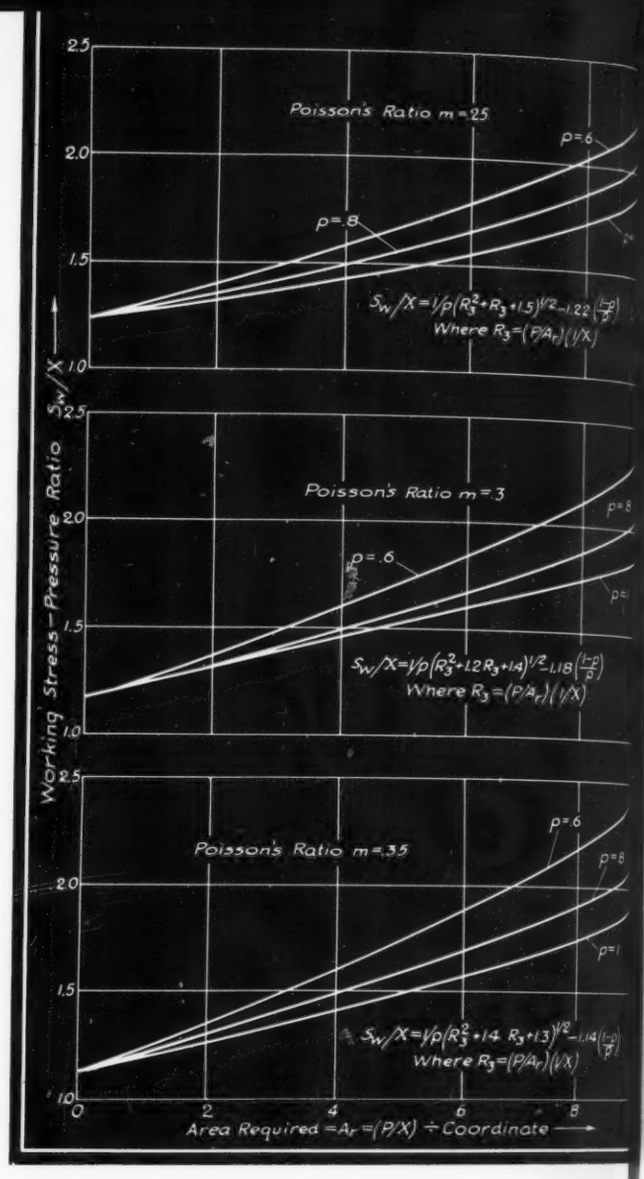


Fig. 22—Required shaft or axle diameter may be determined from these charts when experimental constants are known. Ratio of moduli $E/G = 2.4$

values are also selected and an estimate of the required diameter is made. This determines the ratio S_w/X and from the corresponding coordinate R_3 to the curve, the area $A_r = (P/X)(1/R_3)$ can be found and, hence, the desired diameter of shaft selected.

Comparison of this value with the assumed one can then be made and the procedure repeated until the assumed diameter and the calculated diameter coincide. The allowable axial fluctuating load for a shaft of known diameter can also be selected by using the graphs. This can be done direct since the coordinate S_w/X is known and the corresponding coordinate R_3 to the curve equals P/A_rX. Then, since A_r and X are known, the allowable load P can be selected.

EXAMPLE 4—HOLLOW SHAFT SUBJECT TO SHRINK-FIT PRESSURE, BENDING, TWISTING AND AXIAL LOAD: If the shaft shown in *Fig.* 18 is hollow with an internal radius a and external radius b, the stress components for an element at a distance r from the center are, in place of the values in Equation 4, shown in the following equation:

$$
\left.
\begin{aligned}
S'_z &= \pm\frac{Mr}{I} \pm \frac{P}{A_r}, \quad S''_z = 0, \quad S'_{xy} = S''_{xy} = 0 \\
S'_y &= S''_y = -\left(\frac{b^2}{b^2-a^2}\right)\left(1-\frac{a^2}{r^2}\right)X \\
&= -A\left(1-\frac{a^2}{r^2}\right), \quad S'_{yz} = S''_{yz} = 0 \\
S_x' &= S''_x = -\left(\frac{b^2}{b^2-a^2}\right)\left(1+\frac{a^2}{r^2}\right)X \\
&= -A\left(1-\frac{a^2}{r^2}\right), \quad S'_{zz} = S''_{zz} = \frac{Tr}{J}
\end{aligned}
\right\} \quad \ldots (11)
$$

where $A = Xb^2/(b^2 - a^2)$, and A_r = the shaft area.

These stresses are for completely reversed axial and bending loads and for static torsion combined with shrink-fit pressure. The allowable relationship between the stress components can now be determined by placing the stress values from Equations 11 in Equation 3. By these substitutions,

$$
S_w = \frac{1}{p}\sqrt{\left(\frac{Mr}{I}+\frac{P}{A_r}\right)^2 \pm 4m\left(\frac{Mr}{I}+\frac{P}{A_r}\right) + 2(1-m)A^2\left(1-\frac{a^2}{r^2}\right)^2 + \frac{E}{G}\left(\frac{Tr}{J}\right)^2} - \frac{1-p}{p}\sqrt{2(1-m)\left(1-\frac{a^2}{r^2}\right)^2 A^2 + \frac{E}{G}\left(\frac{Tr}{J}\right)^2}, \quad \ldots\ldots (12)
$$

Equation 12 gives the relationship between the allowable load values for an element at a distance r. To select the critical element it will be necessary to differentiate the right-hand side of Equation 12 with respect to r and to equate to zero. The value of r obtained from the resulting equation defines the critical element and a substitution of this value in Equation 12 gives the allowable relationship between the loads. The above procedure determines the critical element since placing the first derivative of Equation 12 with respect to r equal to zero is equivalent to defining the element subject to the maximum strain energy or the element at which failure would occur.

If for particular combinations of loads the above procedure becomes too complicated mathematically, the critical element can be selected by considering various possible elements as represented by ratios of r/b from a value equal to a/b to a value equal to 1. Using these values in Equation 12 the magnitude of the right-hand side of the Equation can be calculated, and the value of r/b or r for the maximum magnitude represents the position of the critical element. Then this value of r, when substituted in the equation gives the required design formula.

For two-dimensional stress there is some experimental evidence to show that the theory used in the foregoing is a good approximation[4]. It is highly desirable, however, to interpret experiments on shrink-fit assemblies by the strain-energy theory proposed. Tests on shrink-fit assemblies have been made by Kuhnel[5], Thum and Wunderlich[5], Peterson and Wahl[5], Buckwalter, Horger and Sanders[6].

Only a summary of the tests by Peterson and Wahl will be given in this paper. These tests were conducted on medium carbon steel specimens subject to a fluctuating bending moment and a series of press-fit pressures. The pressures were varied to give both a light and a heavy fit between collar and shaft. Two of the specimens were grooved to determine the influence of stress concentration. The test consisted in placing the shaft with the press-fit collar attached in a conventional bending fatigue testing machine where the endurance limit was found by the usual method. The endurance limit was then compared with that obtained from specimens with press-fit pressures.

In the interpretation of their test results, Peterson and Wahl[5] note that the endurance limits for the press-fitted shafts are influenced by three major factors. These are: The three-dimensional combined stress effect, influence of stress concentration, and a rubbing corrosion effect. Although the factors were observed, no attempt was made to evaluate the individual effects of these variables. A study of the test data shows that an approximate

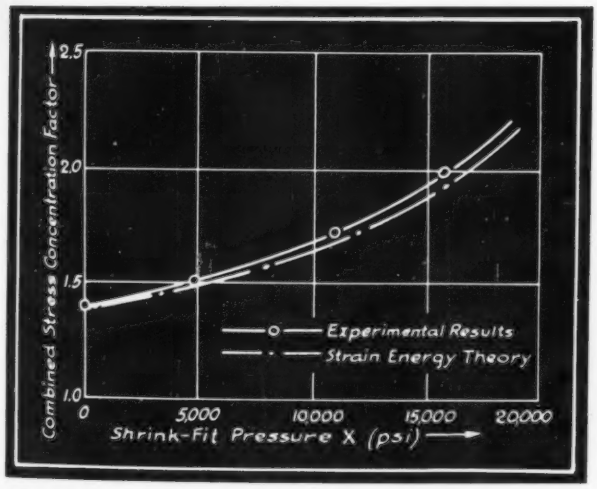
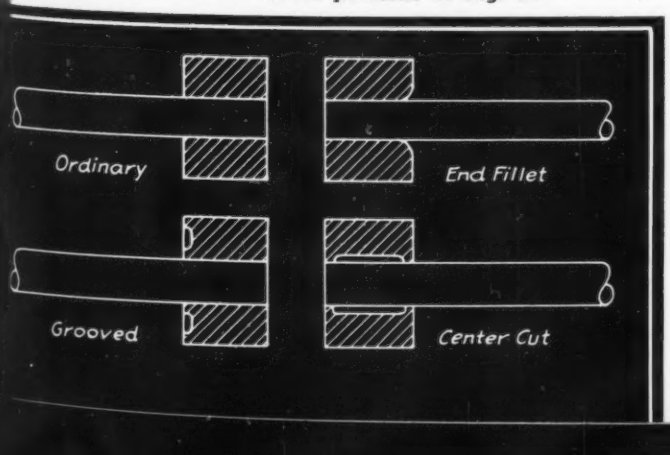


Fig. 23—Comparison of proposed theory with test results on shrink-fit assemblies

Fig. 24—Below—Classification of shrink-fit assemblies. Ordinary and grooved types are shown in the photoelastic stress patterns of Fig. 15



[4] J. Marin—"The Interpretation of Experiments on Combined Fatigue Stresses", *Supplement* to *Journal of the American Welding Society*, May 1942.

[5] A summary of these test results, as well as experiments by Peterson and Wahl, is given in the paper "Fatigue of Shafts of Fitted Members with a Related Photoelastic Analysis", *Transactions*, A.S.M.E., *Journal of Applied Mechanics* March, 1935, Pages 1-11, Peterson and Wahl.

[6] "Modern Locomotive and Axle-Testing Equipment", *Transactions*, A.S.M.E., 1937, Page 225, and "Locomotive Axle Testing", *Transactions*, A.S.M.E., 1938, Page 335.

(*Concluded on Page* 160)

Bearing Seizure as Affected by Surface Finish*

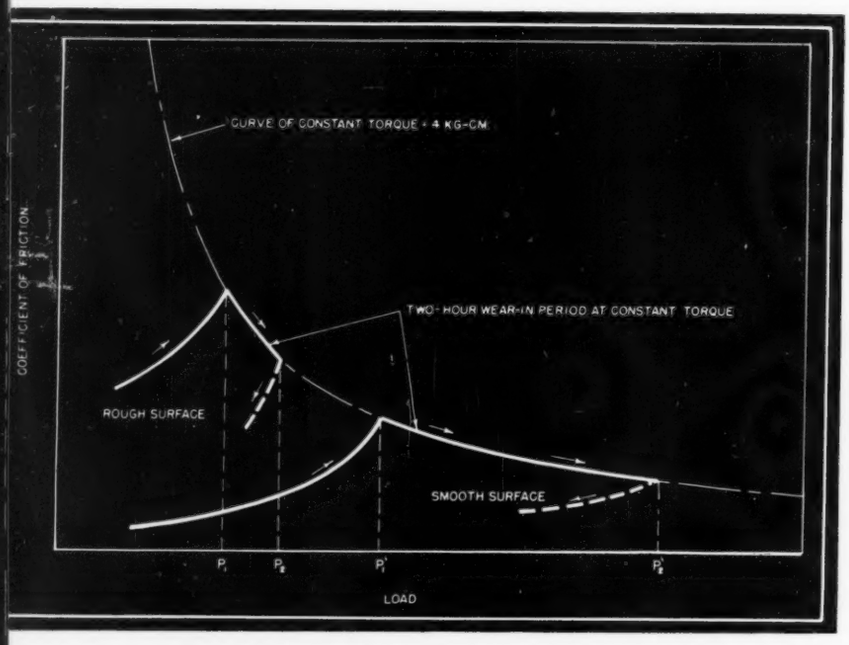
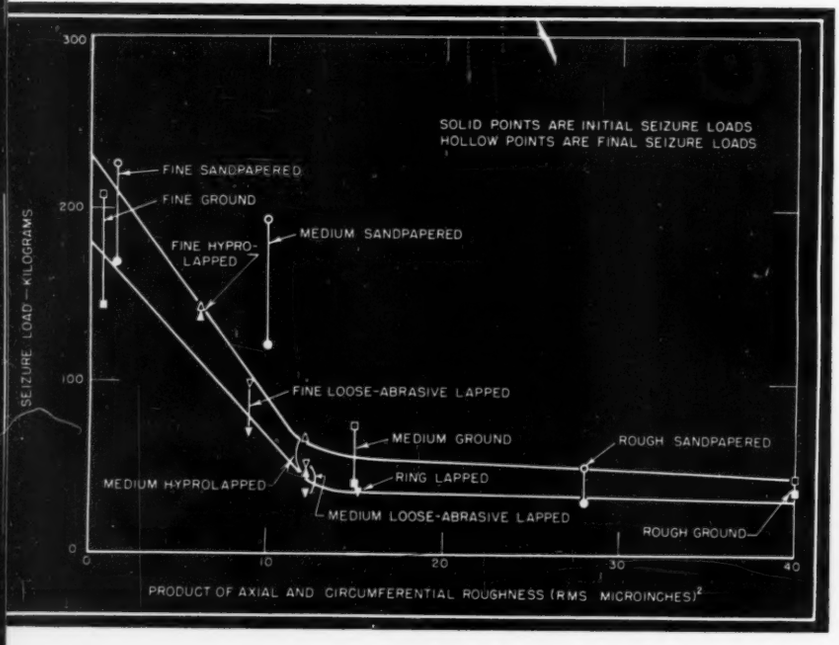


Fig. 1—Above—Characteristic friction-load curves obtained in seizure tests of rough and smooth shafts

Fig. 2—Below—Seizure load is correlated with product of profilometer readings in axial and circumferential directions



FINAL finish put on bearing surfaces in manufacture is vitally important to their behavior in service, particularly during the critical "breaking in" period. Information here presented was obtained as part of a more extensive investigation on the major phases of the performance of abrasively finished surfaces, and deals only with the effect of shaft finish on the seizure of plain bearings. Such seizure, which occurs when hydrodynamic lubrication fails, is a serious problem in heavily loaded, high-speed bearings such as those in the master rod of radial aircraft engines.

Since it was likely that the type as well as the smoothness of a surface would influence seizure, the present investigation was extended to the study of surfaces prepared by various commercial methods. More than one degree of smoothness of each type of surface was investigated. The roughness of the surfaces fell in the range of 1 to 10 root-mean-square micro-inches as read on a profilometer. It is apparent, therefore, that all the surfaces studied fall in the class of fine surface finishes.

Data are reported for steel surfaces finished by grinding, sandpapering, loose-abrasive lapping, and hyprolapping. Tests were made on an S.A.E. 6150 spindle steel hardened to 42 rockwell C. Metallographic examination showed the microstructure to be normal for heat-treated steel of this hardness.

The shaft specimens were prepared by commercial methods and are representative of typical journal finishes in industrial use. No efforts were made to prepare either extremely smooth or extremely rough surfaces. Every effort was made, however, to control the conditions of preparation so that reproducible surfaces could be obtained. The types of finish tested are given in the table.

Seizure tests were made on an Amsler ma-

(*Continued on Page* 164)

* Presented at the recent semiannual meeting of the A.S.M.E. in Cleveland, the paper on which this abstract is based is by R. W. Dayton and H. R. Nelson of the Battelle Memorial Institute, and L. H. Milligan of the Norton company.

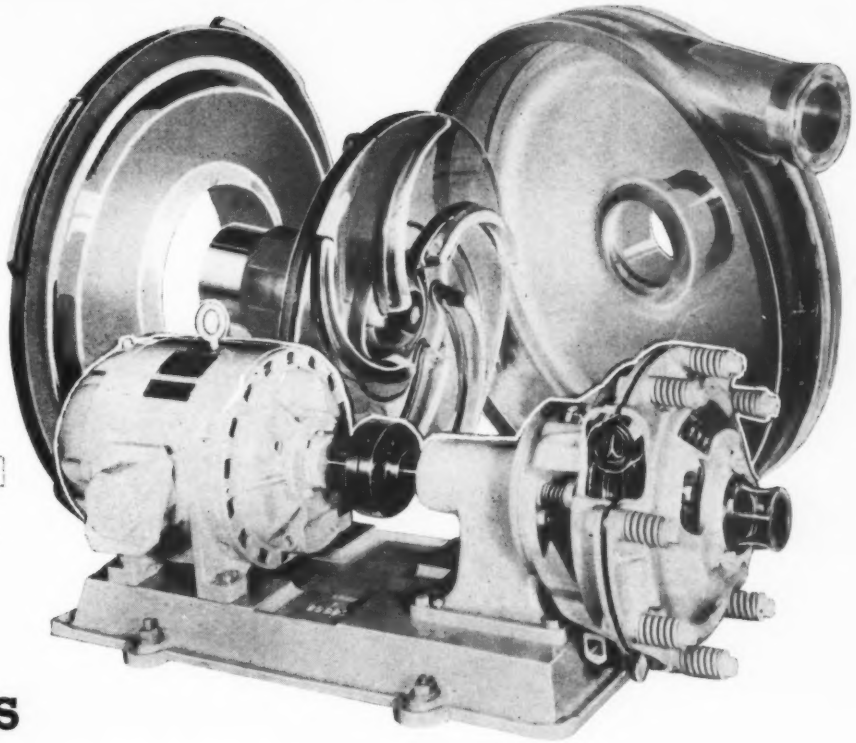


Fig. 1—Impeller and housing of pump used for chemicals are molded glass, ground to accurate dimensions

By Colin Carmichael

Consider Glass In Meeting Materials Shortage

AS AN alternative for other engineering materials glass is playing an increasingly important wartime role. Recent developments in glass production and applications, initiated prior to the present crisis, already presaged a promising future for glass in machine construction. With the need for full exploitation of all national resources to meet the war emergency, new developments are being translated at an accelerated pace into applications where this unique material can replace strategic materials effectively, as well as those where it has earned a place of its own because of its unusual properties. The raw materials of glass—chiefly sand, limestone, salt and borax—face no serious shortage, the main restriction on output being production capacity.

Before designing or re-designing a machine part to be made of glass, as in the case of any unfamiliar material, the engineer will wish to acquaint himself thoroughly with the properties of the material and the limitations set by the manufacturing processes, so that the advantages of using it may be fully developed. It is equally important for him to know when glass cannot be used. Basic considerations affecting the design of glass parts are discussed in the following.

By the very nature of its internal structure glass differs from any other material with which engineers have to deal, and the designer must first re-orient his whole thinking around the fact that glass at all times is a liquid of extremely high viscosity. At normal temperatures the viscosity is, for practical purposes, infinite. At temperatures as high as it is practical to go in glass manufacture the viscosity is still much higher than that of molten metal. This means that bubbles or impurities are not readily freed from the liquid and the liquid will not easily flow into a mold under the influence of gravity alone. Ordinary casting methods are therefore out of the question.

Like other liquids, glass possesses a random orientation of molecules throughout, thus there

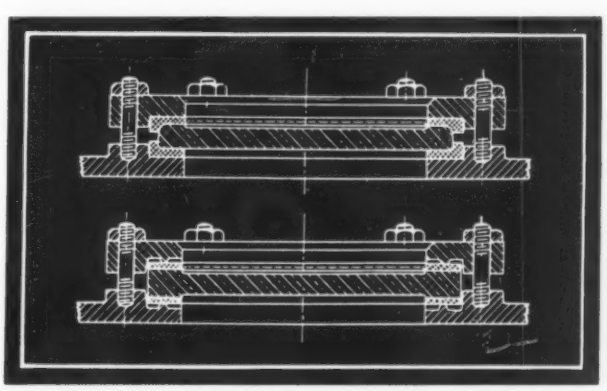


Fig. 2—Mountings for molded sight glasses avoid stress concentrations

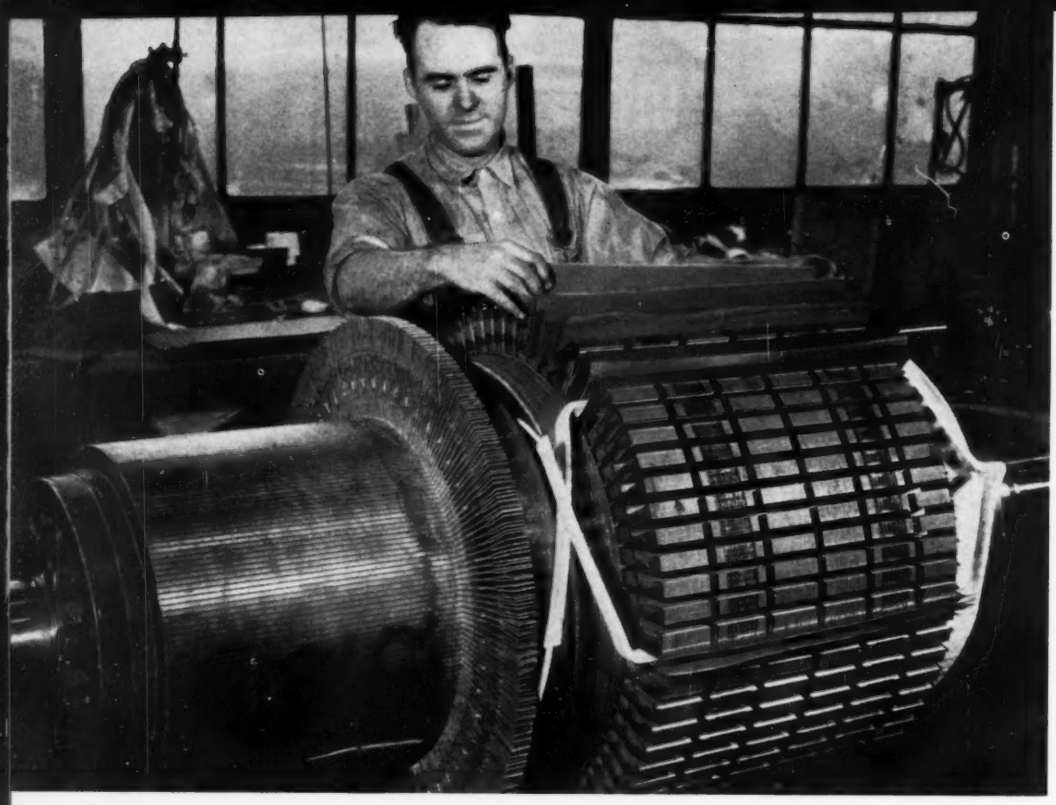


Fig. 3—Mica sheets backed with fiber glass cloth are used for slot or ground insulation

are no slip-planes along which relative movement can take place without fracture, as in crystalline materials such as metals. The high viscosity of glass in the fluid state prevents the molecules from arranging themselves in the form of a space lattice characteristic of solids. An important result of this is complete lack of ductility at normal temperatures, so the material cannot adjust itself to distribute concentrated stresses more uniformly, as metals do, accounting for the apparent fragility of glass.

This brittleness of glass does not necessarily mean weakness or poor shock and fatigue resistance, glass actually being one of the strongest materials known in terms of intermolecular attraction. Failure of glass parts is invariably due to stress concentrations due either to the surface condition or to the manner of loading. Avoidance of stress concentration must be the engineer's chief concern when designing glass parts; however, as will be explained later, in some important cases control of the surface condition may greatly increase the effective strength of glass.

Probably ninety per cent of the glass now made is of the soda-lime-silica variety, the principal raw materials of which are soda ash, limestone and sand. Relative proportions are varied and other materials are often present to the extent of a few per cent in order to give desired properties. Sheet and plate glass, container glasses, electric light bulbs, etc., are of this general type.

From an engineering viewpoint the most important type of glass is the borosilicate, in which the coefficient of thermal expansion is only about one-third that of ordinary lime glasses. Behavior of such glass as pyrex under thermal shock is already well known. In a recent development, borosilicate glass is subjected to a heat treatment which separates it into two distinct phases, one of which is soluble in certain acids and can be leached out. The second phase, rich in silica, is unaffected. After leaching, the glass is heated to a high temperature, the pores left by the dissolved phases close up and the part shrinks to a transparent nonporous glass known as 96 per cent silica glass. With a coefficient of thermal expansion only one-fourth that of borosilicate glass, its resistance to thermal shock is such that white-hot parts can be plunged into cold water without damage.

Bending Tests Measure Strength

Tensile strength of annealed (strain-free) glass is generally of the order of 7,000 to 14,000 pounds per square inch when new. Values generally reported for tensile strength are in terms of the modulus of rupture, calculated from the results of a bending test using the well-known beam formula $s = Mc/I$, where M is the bending moment required to break the piece. Subsequent damage or aging of the surface of the glass may reduce the initial strength values fifty per cent. Freshly-drawn glass fibers a few ten-thousandths of an inch in diameter have been found to possess the astonishing strength of 2,000,000 pounds per square inch.* Merely touching the surface immediately reduces the strength to less than five per cent of this value. Apparently surface flaws of a minute character lead to stress concentrations, causing tensile failure due to the lack of plasticity or ductility.

Substantial increase in the effective strength of certain glass shapes is attained by tempering or thermal toughening. The procedure is to heat the

*C. J. Phillips—*Glass: the Miracle Maker,* Page 72, Pitman Publishing Corp.

part almost to the softening point (about 1150 degrees Fahr.) then rapidly cool the surface by air jets or immersion in a suitable liquid such as an oil or salt bath. Subsequent shrinkage of the hot interior puts the cooled surface in compression and the interior in tension. The surface being in compression is not easily scratched and stress concentrations due to surface defects do not cause fracture because glass is exceedingly strong in compression. When a tempered part is subjected to a bending load the compression in the outer fiber must be relieved before tension at the surface can appear. Much higher bending loads can therefore be sustained.

Tempering Quadruples Strength

For example, a plate glass having a modulus of rupture 6500 pounds per square inch when annealed showed an increase to 29,500 pounds per square inch when tempered. Provided the loading is such that the surface stress never becomes tensile, the part withstands unlimited repetitions without failure by fatigue. Helical springs of tempered glass for corrosion resistance have shown high resistance to fatigue. If a part is to be cut, drilled or fabricated in any way, this work must be done prior to tempering. Tempering does not otherwise change the quality of the glass except to affect the surface flatness and the transmission of polarized light, while fractures form crumbs rather than splinters. It will be evident that tempering is only possible with simple shapes, and so far its principal application has been to plate glass.

A curious and disconcerting property of glass is its delayed breakage characteristic, or tendency to fail after prolonged application of a load, although it is able to sustain a much higher load for a short time. Short-time laboratory tests thus may yield altogether misleading results. Relation between breaking stress and duration of its application may be expressed by an empirical equation of the form $S = A + Bt^{-n}$ where A, B and n are experimental constants. The term A represents the stress which the glass will sustain indefinitely. Detailed information on this type of behavior is scant, and the effect is covered in practice by using large safety factors. When accurate data are available it will be possible to design to closer limits.

Hardness of glass is measured by its resistance to abrasion (Moh's scale) rather than indentation (brinell or rockwell) for the obvious reason that the glass would not deform under an indentation test but simply break. Values of hardness according to Moh's scale (which rates talc as 1, quartz as 7, diamond as 10, etc.) range from 5.5 to 7 for typical glasses. Scleroscope tests have been tried, with some promise of successful correlation with performance in service. Impact tests, likewise, have been made but as in all determinations of this type surface imperfections play such a large role that results are apt to be inconsistent and difficult to interpret.

Up to the breaking point glass is perfectly elastic at normal temperatures, with a tensile elastic modulus approximately 10,000,000 pounds per square inch and Poisson's ratio about .22. Density varies with composition, most commercial types having specific gravity between 2.2 and 2.8, or approximately that of many aluminum alloys. A few glasses are much heavier, some of the lead glasses used for optical purposes weighing as much as cast iron.

Corrosion resistance of certain types of glass is an outstanding property which has led to its wide adoption in the chemical industry. The Nash-Corning centrifugal pump (*Fig.* 1) and the development of glass piping (*Fig.* 4) are notable examples where glass has been used for its unique chemical durability. Not all glasses are equally resistant to chemical action, and some are soluble in water. Borosilicate glass is highly stable in the presence of acids and alkalis in solutions of pH less than 8, except hydrofluoric and glacial phosphoric. Dilute solutions of even these acids and of alkalis of pH above 8 are resisted to a remarkable though lesser degree.

Glass may be used in machines in many of the commercial forms available such as rod, tube, sheet, fiber glass, etc., or it may be molded into special shapes. A rod coiled into a helix and tempered makes an excellent spring for use under corrosive

Fig. 4—Glass piping finds extensive use in chemical and food-processing industries

conditions, as previously noted. Tubing is of course widely used for sight and gage glasses and can be furnished with a bore of precise dimensions where necessary. Precision bore tubes are made by shrinking over a mandrel, can be round, conical or square, with a normal tolerance of plus or minus .0004 inches on the inside dimensions of tubes ranging from .0128 inches to 4 inches. Stricter tolerances can be met if necessary. Examples of such tubes are found in cylinders for pumps and syringes where an accurate plunger must fit tightly.

Annealed sheet and plate glass is replacing sheet aluminum, stainless steel, etc., for doors and covers and is regularly used for fine gaging work, inking plates on printing presses, blueprint machines and partitions. Tempered plate glass may also be used for these purposes and for applications where greater strength is needed such as steam gage guards, oven glazing, observation windows, wind tunnels, marine ports, etc. Tempered plate glass withstands four times the thermal shock (temperature differential) that annealed glass will. It is used preferably where the principal load is bending, so that its advantages may be fully realized.

Sheet glass may be held together in case of fracture by incorporating wire netting in it during manufacture (wire glass) or by making a sandwich of suitable plastic between two sheets of glass (safety glass). Safety glass can be used where the temperature does not exceed 130 degrees Fahr. for long periods or 175 degrees Fahr. for brief exposure. Wire glass naturally will stand higher temperatures, and can be obtained in flat or corrugated sheets. Exceptional strength is secured in multiplate bullet-resisting glass, which has many uses besides that for which it is named and can be obtained in thicknesses up to two inches.

When sight glasses or observation windows must be tightly sealed against pressure, it is important that they be mounted so that high stress concentrations are avoided. Two recommended methods are shown in *Fig.* 2. The frame must support the rim uniformly all around and the gaskets should be resilient. Sight glasses and tubes used with strong

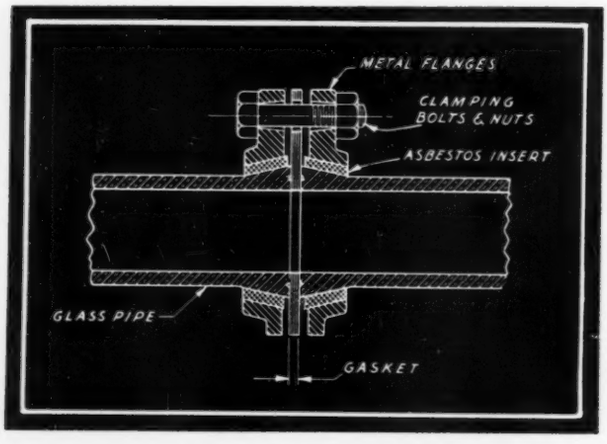


Fig. 5—Flanged pipe joint is so designed that glass is in compression

alkalis must have added thickness to allow for attack and to increase time between replacements.

Fiber glass is made in two forms, staple fiber averaging .00027 inches diameter and 9 inches long and continuous filament of slightly less diameter. It is usually woven into strands about .025 inches diameter, from which it may be made into various yarns and woven into cloth or tape. Principal engineering uses of fiber glass are for electrical insulation, *Fig.* 3, for filter blankets, thermal insulation and sound absorption. The fabric is nonflammable, nonhygroscopic, resists corrosion and is stronger than other textiles, though not as resistant to repeated flexure.

Foam glass which has been foamed or cellulated by the evolution of internal gas under pressure at high temperature is a lightweight form of glass suitable for thermal insulation or as a buoyant material. Possessing a closed cell structure, it is available in block form with a specific gravity as low as .17.

Severe Piping Needs Are Met

Piping of borosilicate glass is being extensively used in places where corrosive conditions are to be met or exceptional cleanliness is desired, as in food-processing machinery. The piping and fittings, *Fig.* 4, are available in nominal sizes from 1 to 3 inches suitable for working pressures up to 100 pounds per square inch, and are provided with conical ends designed for use with the type of flanged connection shown in *Fig.* 5. To allow the necessary freedom for expansion, slip joints (*Fig.* 6) are used where necessary. As heat exchanger tubing glass compares favorably with metallic tubing, especially after a period of use; this is because heat conductance is more affected by film resistance and surface condition than by thermal conductivity. The lower thermal conductivity of glass is offset by the better surface, which is maintained throughout the life of the tube unchanged by the scaling or pitting to which metal tubes may be subject.

Molded glass parts are produced in large quantities by accurately controlled machine methods. It is in this field that the designer has the widest scope for the exercise of ingenuity. Diversified parts such as electrical insulators, centrifugal pump parts (*Fig.* 1), distributor heads for Army motor vehicles, spools and pulleys for the textile industry, etc., are evidence of the rapid strides already made. In designing molded parts the engineer should keep in mind the limitations of the material, which in turn affects the type of mold that can be used.

Molds are cast iron or alloy steel and are usually classified as hot iron, paste and press molds. Hot-iron molds are used continuously and maintained at high temperature. The mold is usually hinged so that it can be opened for removing the part. This type is used for hollow objects which are blown so as to fill the mold. The outside need not

be of circular section and may carry projections or designs on the surface. Control of thickness is not too accurate, surface finish is likely to be poor and a ridge is left on the surface at the parting of the mold. Articles made by this method are approximately bottle-shaped.

Paste molds are somewhat similar to hot-iron molds, but are lined with a paste made from resins and linseed oil or other materials brushed on to the mold and are cooled between each molding operation. The part is revolved while being blown and hence must be circular in cross section. As the paste is wet before each piece is blown, the glass rides on steam as it is revolved and a smooth surface finish is obtained. Parts are made in approximately bottle form for ease in breaking off, as with hot iron molds.

Press molds in their simplest form are used for articles basically of dish form. The mold is in three parts: The bottom or mold proper which defines the outside surface, a power-operated plunger which defines the inside surface and a ring, also power-operated, which defines the top or rim of the part. An accurately-measured gob of plastic glass is dropped into the bottom of the open mold, then the ring and plunger are brought down, squeezing the glass into the mold under enormous pressure. More intricate shapes can of course be made by hinging the mold and parting at one or more surfaces. The high viscosity of

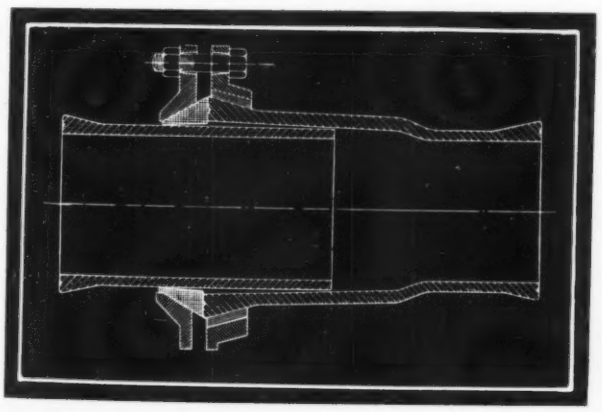


Fig. 6—Slip joints of simple design provide necessary flexibility in pipe runs

glass makes difficult the forcing of the fluid into small cavities. Tendency of the glass to cool before it flows into a small section may be offset by proper temperature control of the mold, but this is troublesome and is the main reason why glass molded parts in general are of the simplest possible shape. Small straight-through holes are practically impossible to mold satisfactorily, and where such are required they are molded blind and later opened by a grinding drill or heated locally and blown out.

Font molding is an extension of the press mold, in which the plunger forces the glass through

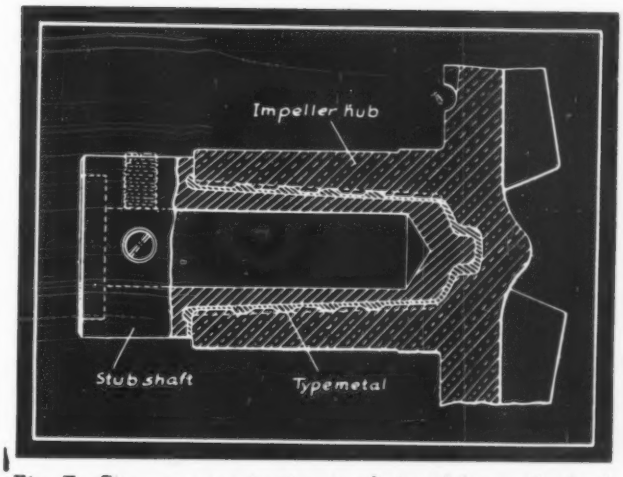


Fig. 7—Stress concentration is obviated by method of attaching glass pump impeller to shaft

narrow radial openings into a number of individual hollow molds of the desired shape. After molding the parts must be separated from the sprues.

Larger, more intricate parts than can be molded in one piece are made by attaching two or more simple molded pieces. Joined by sealing, the part may be just as strong and homogeneous as if made in one piece. Sealing is done by heating the edges to be joined to the softening point and bringing them together under slight pressure. The work may be done rapidly by the use of suitable fixtures and equipment. Glasses of various types (different thermal expansion characteristics) are joined by using a series of properly graded sealing glasses of intermediate properties.

Electrical Heating Speeds Operations

A new technique for finishing, cutting or welding glass parts uses the fact that at high temperature glass is a good electrical conductor. The preheated parts are exposed to high frequency electrical waves from a suitable oscillator; currents flowing through the electrically conducting hot glass further heat the glass at a controlled rate and in exactly the right places as determined by the location of the electrodes. In this manner fast penetration of heat into thick sections is attained and welding, cutting or hole-punching operations can be performed without damage to surrounding parts.

Tolerances on molded glass parts are affected by the precision with which the molds are made, the effect of mold wear, glass shrinkage, temperature variations during cooling, etc. Where a high degree of precision is needed in the finished part, grinding is used. Tempered parts, which suffer slight distortion during heat treatment, may be ground to finished size provided the amount of material removed is not too great.

In designing machine parts of glass it is im-

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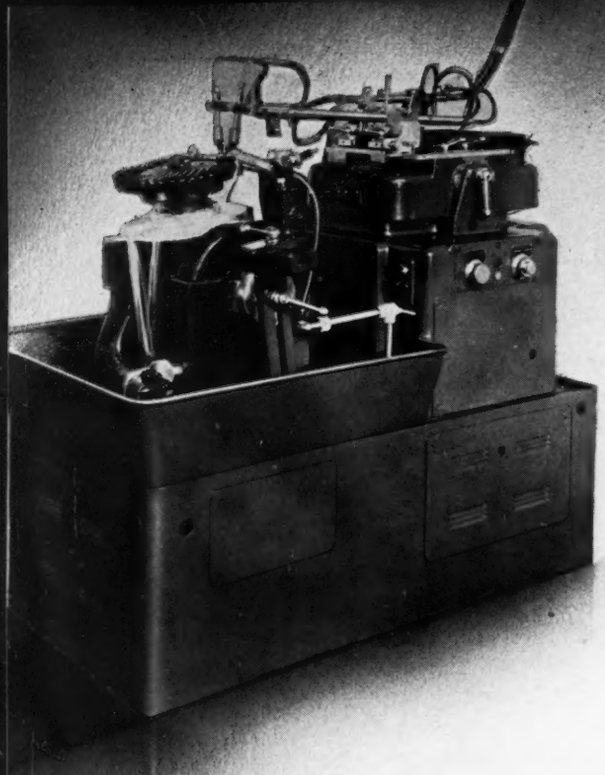

Above—Variable rate of travel of the burner slide is provided in the Gleason surface-hardening machine, to give a progressively increasing or decreasing velocity and compensate for changing tooth section of bevel gears. Hardening operation is completely automatic

Below—Sustained operation at high loads is made possible in the Lincoln shield-arc junior welder through the use of nonflammable materials throughout, including glass-covered wires for the coil windings. Voltage and current control are self-indicating, simplifying setting by the operator

Above—Cleaning and s
machine parts ast
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Below—Handling 5-ton loads at 5½-foot radius, the Baker truck meets heavy-duty requirements of the war program. Power unit—battery or gas-electric—serves as counterweight for the load, effecting a saving in overall weight

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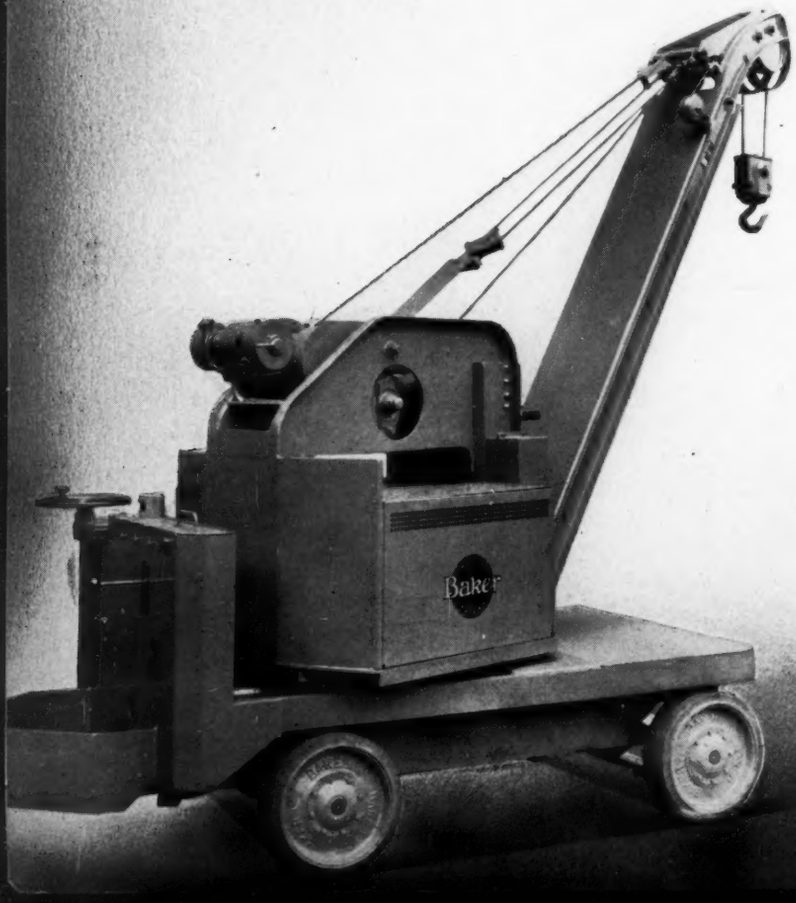

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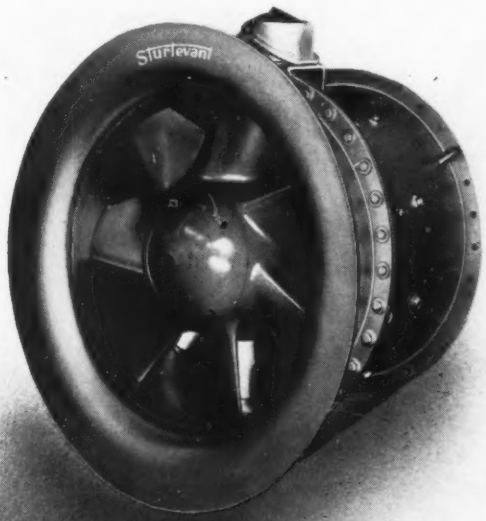
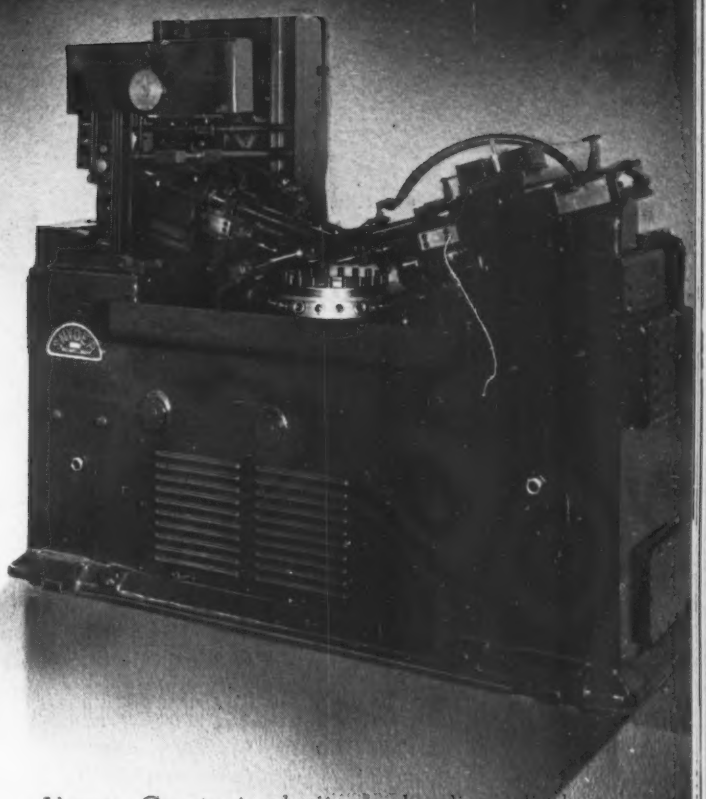
Below—Restricted to the Navy for the duration of the war, the Sturtevant victory fan is in extensive use for ventilating and mechanical draft service aboard fighting ships. High speed results in compact design without impairing quiet operation





Above—Constant-velocity hydraulic cylinders actuating a geneva index mechanism rotate the fixture table of the Snyder drilling machine. Electric control includes a tell-tale dial which shows at what part of the automatic cycle the machine is operating. Forty holes are drilled in twenty index positions

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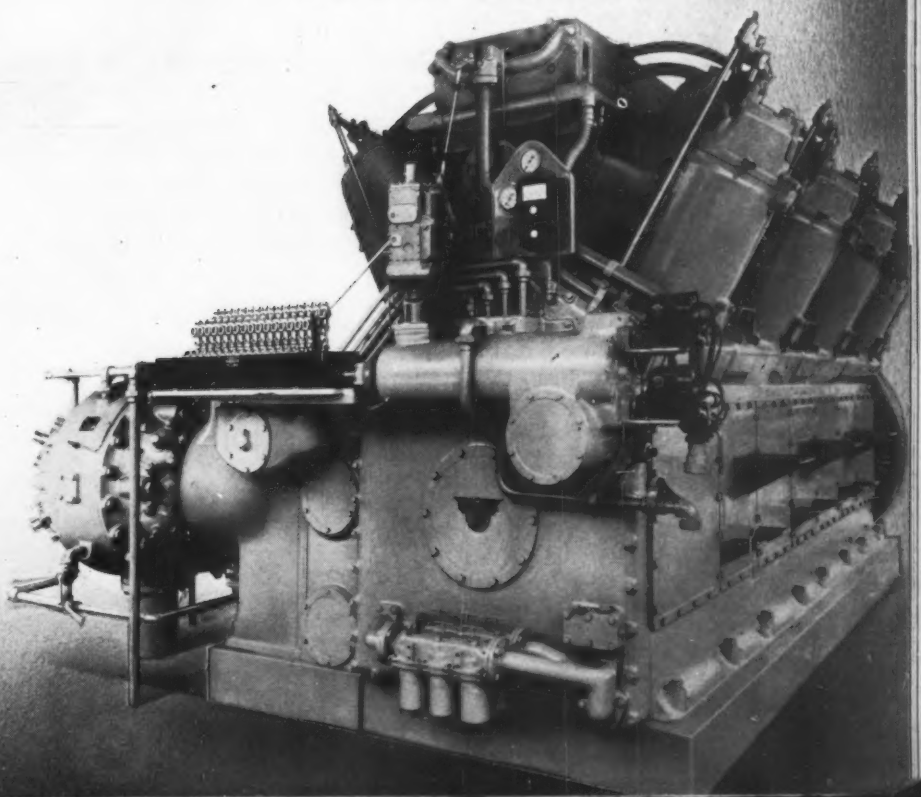
Below—Compact compressor capacity of the Cooper-Bessemer unit is obtained with less than half the floor space required by a horizontal unit of equal power. A two-cycle fuel-injection V-type gas engine drives a horizontal scavenging pump and compressor in tandem, using articulated connecting rods



—Diesel-propelled, the Adams grader has forward speeds and a wide range of blade ment including bank cuts. Weight distribu- balanced to provide sufficient traction, blade re, scarifier pressure and front-end control

MACHINE DESIGN *Editorial*

Do It Now—Every Designer Can Improve Materials Situation

SOME months ago it was intimated on this page that the limit of American production might well be reached in the near future—not because of the nonavailability of manpower or plants but due to shortages of materials. Such a situation seems to be drawing rapidly closer. The supply of raw materials is not nearly keeping pace with the ever-increasing production of war equipment.

Supplies of basic materials, within limits, can be increased. Substitution by synthetics will grow, though slowly. Purchase of idle inventories of one plant by another will ease the situation temporarily, as will collections and segregation of scrap. All of these factors collectively may prove sufficient to tide the country over the dire need—but only if the designers of military equipment apply the materials available to them with the primary thought in mind of efficiency and conservation.

Donald M. Nelson hit the nail on the head in a recent address: "If I could give you just one message I would like to say—continue to be ingenious. Never for a moment let up in your search for ways of doing more, faster, with less. You have the chance to revolutionize the whole art of producing for war. And until victory has been won this nation's only thought must be producing for war." This was said before a general meeting of executives of the automotive industry, but the remarks apply equally well to engineers responsible for design.

It is to the designer's everlasting credit that innumerable successful efforts to effect substitution and consequent conservation have already been made. One of the most notable is the utilization of molybdenum steels in place of the critical nickel alloys; another the employment of plastic materials including fully-impregnated plywood; and still another, though more remote, the application of glass for machine parts as discussed in an article in this issue. Through the increasing use of silver, tin has been markedly conserved, and satisfactory substitutes for aluminum, zinc and steel have been found for many types of machine parts.

That there is still much to be done is becoming daily more apparent. Effective evidence of this, from an overall standpoint, can readily be found in the compilation of MACHINE DESIGN'S forthcoming directory of materials now under preparation. More and more materials are limited to war uses only, some being on strict government allocation. May the supplies of these, through continued resourcefulness and realization of need on the part of designers, prove amply adequate to serve the nation's ultimate purpose.

L. E. Jerry

Graphical Analysis of Planetary Gear Systems—Part I

By Guy J. Talbourdet*
Research Division
United Shoe Machinery Corporation

SOLVING planetary gearing problems by vectors and instant centers materially assists visualization and also furnishes important information not given by conventional methods. The method is introduced in this article and data sheets summarizing the results will be presented in three parts beginning with this issue

WHEN a gear drive departs from simple pairs or trains as in planetary or epicyclic gearing where some of the axes of the gears are also in motion, calculations become more complex. These calculations involve the determination of the speed ratios between the driving and driven members, the direction of rotation and angular velocity of the intermediate and driven members, the relative pitch line velocities of driving and driven gears, and the tooth and bearing loads. Such cases call for a careful analysis of the entire system, for not only are the tooth loads sometimes higher than in simple gear trains, but the pitch line velocity of tooth engagement or relative pitch line velocity of the meshing gear teeth is often higher than the pitch line velocity at which the load is actually transmitted.

Furthermore, the tooth friction power losses do not depend on the tangential tooth load and the pitch line velocities of the driving and driven gears about their axes of rotation, but on the tangential tooth load and the pitch line velocity of engagement between gear teeth. Again, the dynamic tooth load must be calculated from the pitch line velocity of engagement and not from the pitch line velocities of the driving and driven gears about their own axes.

While some literature is available on the gear design of planetary drives—among which are *Spur Gears* (Chapter 7) and *Manual of Gear Design* (Section 2) by Earle Buckingham, where the importance of a careful analysis of planetary gearing is especially stressed—it is felt that an analysis of the kinematics of planetary or epicyclic drives in which a visualization of the motion of the various elements can be readily obtained will be of interest to machine designers and give a better understanding of the factors involved.

Such a visualization is realized by the introduction of velocity vectors and instantaneous axes of rotation in the solution of the problem. When the motion of the various elements is uniform, the solution may be either graphical or analytical; when variable, the analytical solution must be used. The method is equally applicable whether the angular velocity of the driving member is uniform or variable, also when more than one member in the system is driving. To simplify the analysis, the pitch radius of the gears rather than the number of teeth is used, as it gives a better picture of the problem.

To illustrate the method, let us consider a simple planetary gear train consisting of a fixed internal gear, S_2, a planet pinion, P, a driving sun gear, S_1, rotating in a clockwise direction, and a driven arm, A, as shown in *Fig.* 4 on the data sheet, Page 95. Referring to the nomenclature, $\omega_{s1}R_{s1}=$

Nomenclature

ω_{s1} = angular velocity of sun gear S_1
ω_{s2} = angular velocity of sun gear S_2
ω_p = angular velocity of planet pinions
R_{s1} = pitch radius of sun gear S_1
R_{s2} = pitch radius of sun gear S_2
R_p = pitch radius of planet pinion P
R_a = length of arm A from O_s to O_p
O_s = center of rotation of sun gears
O_p = center of rotation of planet pinions
P_1 = pitch point of gear S_1 and pinion P
P_2 = pitch point of gear S_2 and pinion P
V_{s1} = pitch line velocity of sun gear S_1
V_{s2} = pitch line velocity of sun gear S_2
V_{c1} = pitch line velocity of engagement of gear S_1 and pinion P
V_{c2} = pitch line velocity of engagement of gear S_2 and pinion P
V_a = linear velocity of center O_p of planet pinion

* This article was started in co-operation with the late J. N. Sinnott.

V_{s_1}. From pitch point p_1 velocity vector V_{s_1} is drawn tangent to the pitch circles of gear S_1 and pinion P and in the direction of rotation of sun gear S_1.

Since sun gear S_2 is fixed, the momentary contact point p_2 common to the teeth of gear S_2 and pinion P has no velocity and hence becomes the instantaneous axis of planet pinion P, which means that at that instant pinion P swings or rotates about axis p_2. Then if the linear velocity of a point in the planet pinion is known, the linear velocity of any other point in the pinion can easily be determined. This fact is important because it permits the finding of linear velocity of center O_p of planet pinion P when the linear velocity of pitch point p_1 in the planet pinion is known.

Point p_1 being common to gear S_1 and pinion P, the linear velocity of point p_1 on pinion P is therefore V_{s_1}. The linear velocity of center O_p is then determined by joining the end of vector V_{s_1} to instantaneous axis p_2 and drawing vector V_a parallel to V_{s_1}. Vector V_a is the linear velocity of center O_p of planet pinion P and has the same direction as velocity vector V_{s_1}. Since O_p is common to pinion P and arm A, the angular velocity of arm A about center O_s is therefore $\omega_a = V_a/R_a$, and as velocity vector V_a has the same direction as vector V_{s_1}, arm A rotates in the same direction as gear S_1.

Velocity of Engagement Found

To determine the pitch line velocity of engagement, a line is drawn passing through center O_s and end of vector V_a. Then from instantaneous axis p_2 draw p_2N_2 parallel to V_a. p_2N_2 or V_e, as it will be called, is the pitch line velocity of engagement between the teeth of pinion P and sun gear S_2. Since $p_2N_2 = V_{s_1} - p_1N_1$, V_e is also the pitch line velocity of engagement between the teeth of planet pinion P and sun gear S_1. But the pitch line velocity of engagement V_e is also the pitch line velocity of planet pinion P about its own center of rotation O_p. Then $\omega_p = V_e/R_p$ and its direction of rotation is opposite to that of gear S_1, or counterclockwise.

From the geometrical conditions of *Fig.* 4, $V_a = V_{s_1}/2$. But $V_a = \omega_a R_a$ and $V_{s_1} = \omega_{s_1} R_{s_1}$. Then $\omega_a = \omega_{s_1} R_{s_1}/2R_a$ and $\omega_a/\omega_{s_1} = R_{s_1}/2R_a$ which is the speed ratio between the driven and driving members.

For the pitch line velocity of tooth engagement of sun gear S_2 and pinion P, $V_{e_2} = V_{s_2} - p_2N_2 = 0 - p_2N_2 = -p_2N_2$ and $p_2N_2/V_a = R_{s_2}/R_a$ or $p_2N_2 = R_s V_a/R_a = \omega_a R_{s_2} = -V_{e_2}$.

For the pitch line velocity of tooth engagement of sun gear S_1 and pinion P, $V_{e_1} = V_{s_1} - p_1N_1$. But $p_1N_1/V_a = R_{s_1}/R_a$ or $p_1N_1 = R_{s_1}V_a R_a = \omega_a R_{s_1}$; and hence $V_{e_1} = 2\,\omega_a R_a - \omega_a R_{s_1} = \omega_a\,(2\,R_a - R_{s_1}) = \omega_a R_{s_2}$, or $V_{e_1} = -V_{e_2}$.

This shows that the pitch line velocities of engagement of the sun gears with planet pinion P are equal but of opposite sign.

Since the velocity of tooth engagement V_e is also the pitch line velocity of the planet pinion about its own center of rotation, the angular velocity of pinion P about O_p is $\omega_p = V_e/R_p = \omega_a R_{s_2}/R_p$ and to find its direction of rotation it is only necessary to observe that V_{s_1} is greater than p_1N_1 which means that V_{e_1} has the same direction as V_{s_1} and causes planet pinion P to rotate counterclockwise with respect to center O_p.

The same procedure can be used whether either sun gear or the arm is fixed, driving or driven. The results for these conditions are given in the engineering data sheets.

When the angular velocity of the driver is variable, it is only necessary to let $\omega = f(t)$ where the $f(t)$ expresses algebraically the angular velocity of the driving member at any instant.

In the gear tooth design of planetary gearing it is often necessary to enlarge the small sun gear or the planet pinion in order to eliminate undercut of gear teeth and obtain more favorable tooth contact conditions. In such cases, the pitch radii of operation of the gears and not their nominal pitch radii should be used. Thus, when N_{s_1} = number of teeth in gear S_1, N_{s_2} = number of teeth in gear S_2, N_p = number of teeth in planet pinion P, C_1 = center distance between gear S_1 and pinion P, and C_2 = center distance between gear S_2 and pinion $P = C_1$, we have, $R_{s_1} = N_{s_1} \times C_1/(N_{s_1} + N_p)$, $R_{s_2} = N_{s_2} \times C_2/(N_{s_2} - N_p)$ and $R_p = N_p \times C_1/(N_p + N_{s_1})$.

So far the case when one member only is driving, has been considered. The planetary train above will now be analyzed when sun gears S_1 and S_2 are both driving and arm A is driven.

Inspection of *Fig.* 6 shows that point i is the instantaneous axis of rotation of planet pinion P. Here sun gears S_1 and S_2 rotate in the same direction but the following analysis holds true if these gears rotate in opposite directions.

From the geometrical conditions in *Fig.* 6, $V_a = V_{s_2} + (V_{s_1} - V_{s_2})/2 = (V_{s_1} + V_{s_2})/2$. But $V_a = \omega_a R_a$, $V_{s_1} = \omega_{s_1} R_{s_1}$, and $V_{s_2} = \omega_{s_2} R_{s_2}$. Therefore the angular velocity of the driven arm A is $\omega_a = (\omega_{s_1} R_{s_1} + \omega_2 R_{s_2})/2R_a$.

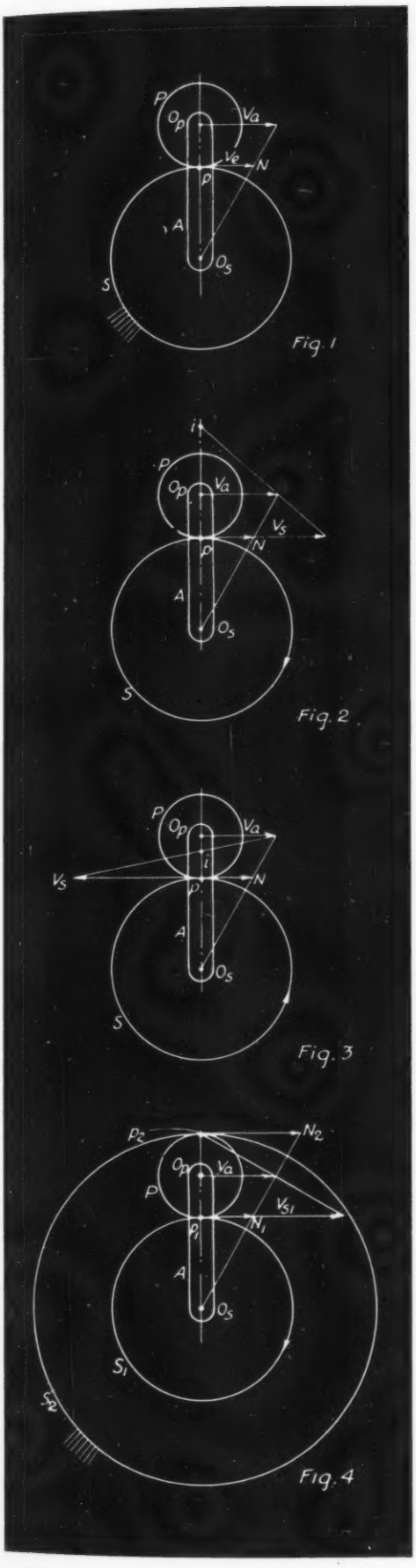
Pitch line velocity of engagement of sun gear S_1 with planet pinion P is $V_{e_1} = V_{s_1} - p_1N_1$, but $p_1N_1 = R_{s_1}V_a/R_a$; hence $V_{e_1} = R_{s_1}(\omega_{s_1} - \omega_a)$.

Angular velocity of planet pinion P is $\omega_p = R_{s_1}(\omega_{s_1} - \omega_a)/R_p$. As sense of vector V_a indicates, arm A rotates in a clockwise direction and since vector V_{s_1} is greater than vector p_1N_1, planet pinion P rotates counterclockwise.

The same procedure is applicable if the arm of the sun gears is driving. The results of these conditions are given in the engineering data sheets.

In the preceding analysis simple internal planetary gearing has been dealt with; the same procedure can also be used for simple external planetary gearing, the results of which are also given in the engineering data sheets.

Planetary Gearing Systems—I



Simple External Planetary Gearing

Sun gear S fixed, arm A driving clockwise—Fig. 1

$\omega_s = 0 \qquad V_e = \omega_a R_a$

Pitch line velocity of tooth engagement is $V_e = pN = \omega_a R_s$

Angular velocity of planet pinion P about O_p is $\omega_p = \dfrac{\omega_a R_s}{R_p}$

Planet pinion rotates clockwise.

Sun gear S and arm A driving clockwise—Fig. 2

$V_s = \omega_s R_s \qquad V_a = \omega_a R_a$

Pitch line velocity of tooth engagement is $V_e = V_s - pN = R_s(\omega_s - \omega_a)$

Angular velocity of planet pinion about O_p is $\omega_p = \dfrac{R_s}{R_p}(\omega_s - \omega_a)$

When $V_s > pN$ pinion P rotates counterclockwise

When $V_s = pN$ pinion P is stationary about O_p

When $V_s < pN$ pinion P rotates clockwise.

Sun gear S driving counterclockwise, arm A driving clockwise—Fig. 3

$V_s = \omega_s R_s \qquad V_a = \omega_a R_a$

Pitch line velocity of tooth engagement is

$V_e = -V_s - pN = -R_s(\omega_s + \omega_a)$

Angular velocity of planet pinion P about O_p is $\omega_p = \dfrac{R_s}{R_p}(\omega_s + \omega_a)$

Planet pinion rotates clockwise.

Simple Internal Planetary Gearing

Sun gear S_1 driving clockwise, sun gear S_2 fixed, arm A driven—Fig. 4

$\omega_{s2} = 0$, $V_{s1} = \omega_{s1} R_{s1}$. Then $V_a = \dfrac{V_{s1}}{2}$

Angular velocity of driven arm is $\omega_a = \dfrac{\omega_{s1} R_{s1}}{2 R_a}$

Speed ratio is $\dfrac{\omega_a}{\omega_{s1}} = \dfrac{R_{s1}}{2 R_a}$

Pitch line velocity of tooth engagement is $V_{e2} = p_2 N_2 = \dfrac{V_a R_{s2}}{R_a} = \omega_a R_{s2}$

Angular velocity of planet pinion about O_p is $\omega_p = \dfrac{\omega_a R_{s2}}{R_p}$

Driven arm A rotates clockwise and planet pinion P rotates counterclockwise.

When arm A is driving clockwise, sun gear S_2 is fixed and sun gear S_1 is driven, the foregoing equations for V_e and ω_p and the directions of rotation of sun gear S_1 and pinion P hold true, but

$\omega_{s1} = \dfrac{2\omega_a R_a}{R_{s1}}$ and $\dfrac{\omega_{s1}}{\omega_a} = \dfrac{2R_a}{R_{s1}}$.

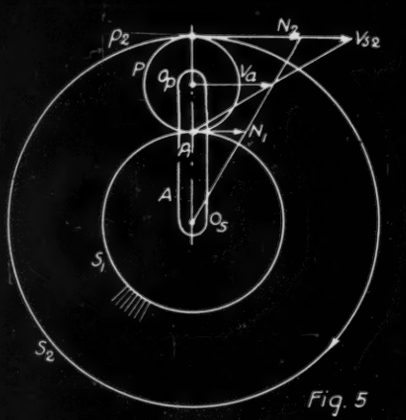


Fig. 5

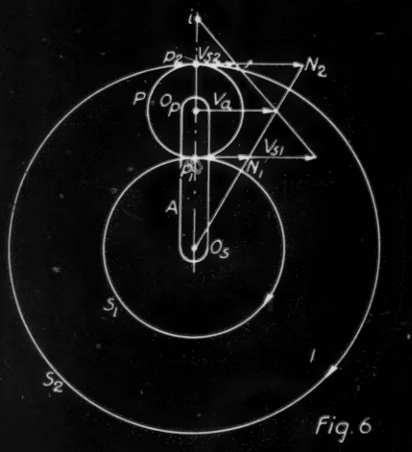


Fig. 6

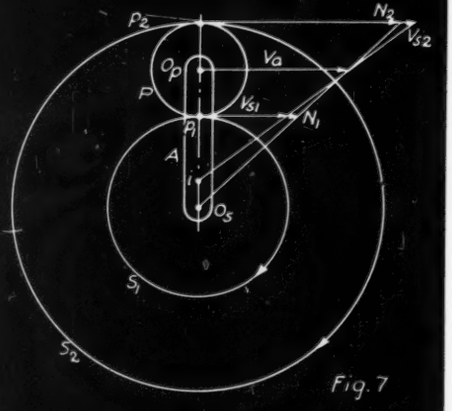


Fig. 7

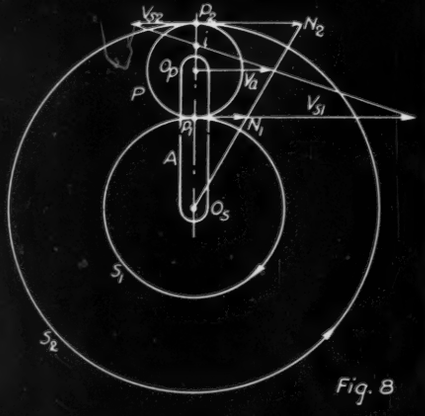


Fig. 8

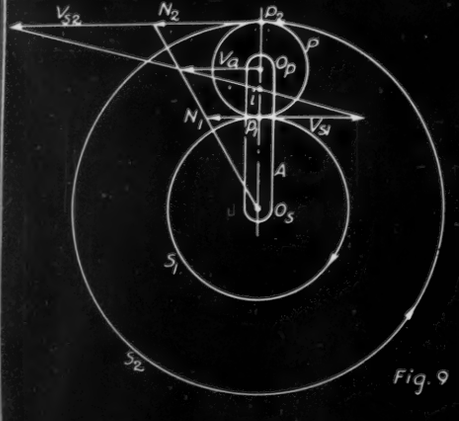


Fig. 9

Sun gear S_2 driving clockwise, sun gear S_1 fixed, arm A driven—Fig. 5

$$\omega_{s1}=0, \qquad V_{s2}=\omega_{s2}R_{s2}.$$

$$\text{Then } V_a=\frac{V_{s2}}{2} \qquad \omega_a=\frac{\omega_{s2}R_{s2}}{2R_a} \qquad \frac{\omega_a}{\omega_{s2}}=\frac{R_{s2}}{2R_a}$$

$$V_{e1}=0-p_1N_1=-\omega_aR_{s1} \qquad \omega_p=\frac{\omega_aR_{s1}}{R_p}$$

Driven arm *A* and planet pinion *P* rotate clockwise.

When arm *A* is driving clockwise, sun gear S_1 is fixed and sun gear S_2 is driven, the foregoing equations for V_e and ω_p and the directions of rotation of sun gear S_2 and pinion P hold true, out

$$\omega_{s2}=\frac{2\omega_aR_a}{R_{s2}} \quad \text{and} \quad \frac{\omega_{s2}}{\omega_a}=\frac{2R_a}{R_{s2}}.$$

Sun gears S_1 and S_2 driving clockwise, V_{s1} greater than V_{s2}, arm A driven—Fig. 6

$$V_{s1}=\omega_{s1}R_{s1} \qquad V_{s2}=\omega_{s2}R_{s2}$$

$$\text{Then } V_a=\frac{V_{s1}+V_{s2}}{2} \qquad \omega_a=\frac{\omega_{s1}R_{s1}+\omega_{s2}R_{s2}}{2R_a}$$

$$V_{e1}=V_{e2}=V_{s1}-p_1N_1=R_{s1}(\omega_{s1}-\omega_a) \qquad \omega_p=\frac{R_{s1}}{R_p}(\omega_{s1}-\omega_a)$$

Driven arm *A* rotates clockwise and planet pinion rotates counterclockwise.

Sun gears S_1 and S_2 driving clockwise, V_{s1} less than V_{s2}, arm A driven—Fig. 7

When $\omega_{s2}>\omega_{s1}$, instantaneous axis *i* is above center O_s.

$$V_{s1}=\omega_{s1}R_{s1} \qquad V_{s2}=\omega_{s2}R_{s2}.$$

The equations given in connection with Fig. 6 and the directions of rotation of arm *A* hold true, but the direction of rotation of planet pinion *P* is clockwise.

When $\omega_{s2}<\omega_{s1}$, instantaneous axis *i* is below center O_s and the equations given in connection with Fig. 6 hold true. The directions of rotation of driven arm *A* and planet pinion *P* also hold true.

Sun gear S_1 driving clockwise, sun gear S_2 driving counterclockwise, V_{s1} greater than V_{s2}, arm A driven—Fig. 8

$$V_{s1}=\omega_{s1}R_{s1} \qquad V_{s2}=\omega_{s2}R_{s2}$$

$$\text{Then } V_a=\frac{V_{s1}-V_{s2}}{2} \qquad \omega_a=\frac{\omega_{s1}R_{s1}-\omega_{s2}R_{s2}}{2R_a}$$

$$V_{e1}=V_{e2}=V_{s1}-p_1N_1=R_{s1}(\omega_{s1}-\omega_a) \qquad \omega_p=\frac{R_{s1}}{R_p}(\omega_{s1}-\omega_a)$$

Driven arm *A* rotates clockwise and planet pinion *P* rotates counterclockwise.

Sun gear S_1 driving clockwise, sun gear S_2 driving counterclockwise, V_{s1} less than V_{s2}, arm A driven—Fig. 9

$$V_{s1}=\omega_{s1}R_{s1} \qquad V_{s2}=\omega_{s2}R_{s2}$$

$$\text{Then } V_a=\frac{V_{s2}-V_{s1}}{2} \qquad \omega_a=\frac{\omega_{s2}R_{s2}-\omega_{s1}R_{s1}}{2R_a}$$

$$V_{s1}=V_{e2}=V_{s1}-(-p_1N_1)=R_{s1}(\omega_{s1}+\omega_a) \qquad \omega_p=\frac{R_{s1}}{R_p}(\omega_{s1}+\omega_a)$$

Driven arm *A* and planet pinion *P* rotate counterclockwise

When $V_{s1}=-V_{s2}$, then $V_a=0$, $V_{e1}=V_{s1}$ and $\omega_p=\frac{\omega_{s1}R_{s1}}{R_p}$.

Arm A is stationary and planet pinion rotates counterclockwise.

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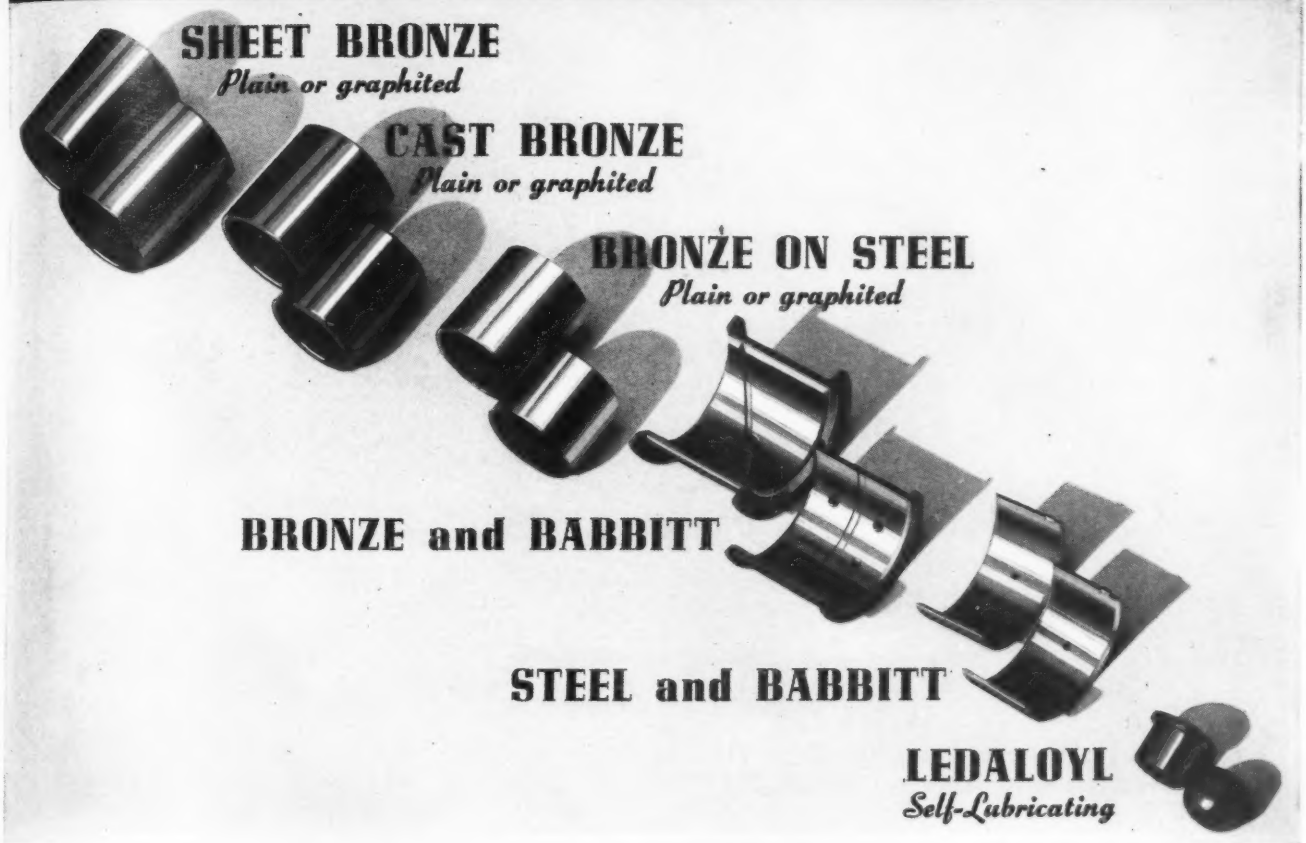

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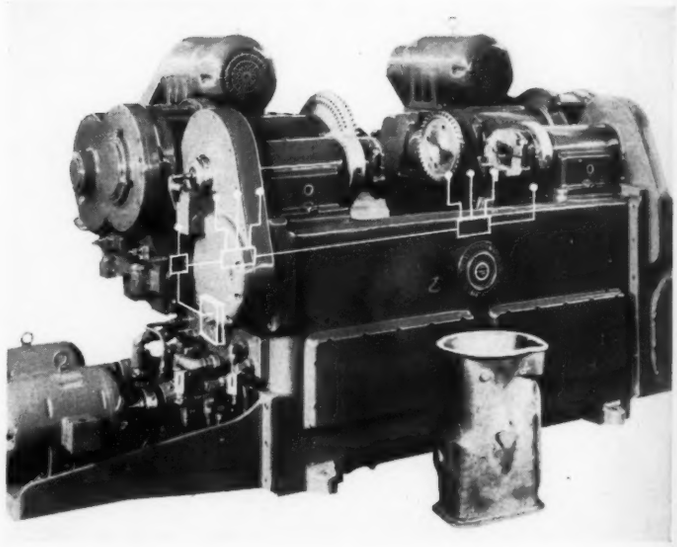
Applications

of Engineering Parts and Materials

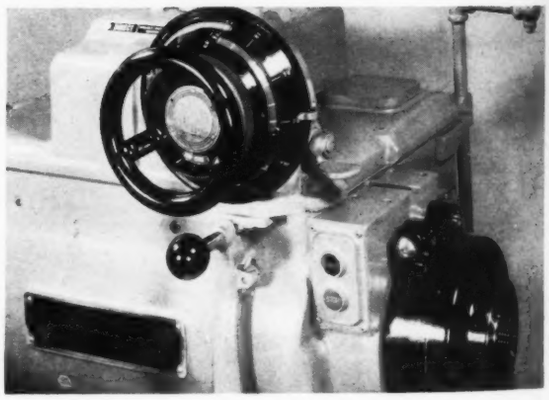
Controls Timed Lubrication

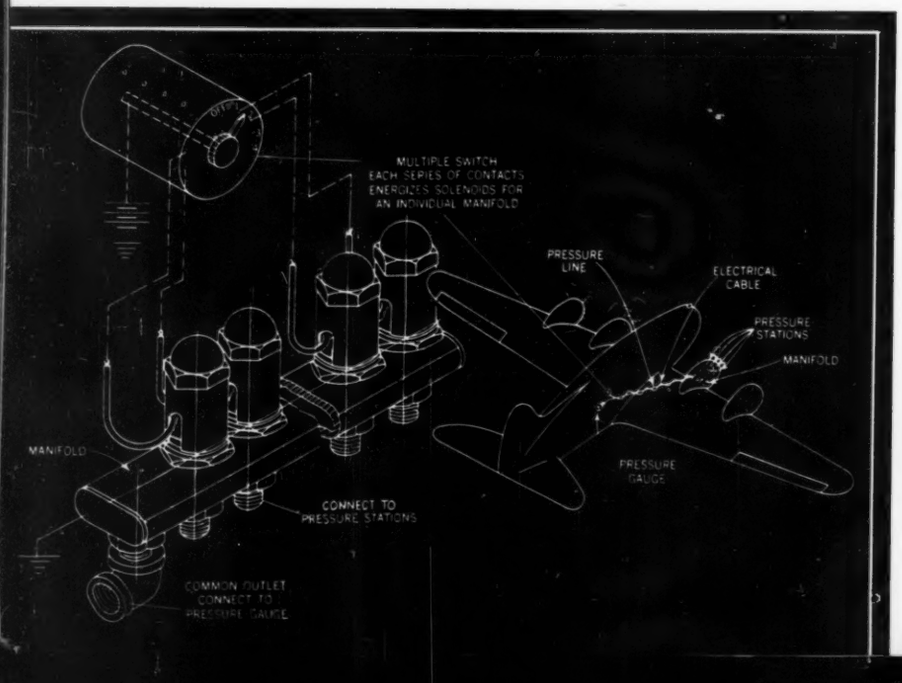
Centralized automatic lubrication is used on the RMZ Rotomill shown set up for facing the ends of tractor crankcases. Pump and reservoir unit, lower left, together with branched oil feedline, junctions and meter units at the bearing surfaces comprise the Bijur system. A switch connected to one of the machine slides energizes the solenoid on the return stroke. At the end of the return stroke the current to the solenoid is shut off, the lubricator pump piston descends and oil is delivered through the distribution feedline tubing to the eight meter units. Each meter unit feeds a predetermined quantity of oil to the bearing surface it serves. Thus the lubricator is operated once each cycle of the machine.



Molded Plastics Replace Aluminum

Control wheel and dial for the speed selector on the new Gisholt turret lathe are high-impact plastic. Numbers on the dial are easy to read, while the contrast between the black outer dial and red inner dial adds to visibility. Another plastic part on the machine is a twelve-inch handwheel used for longitudinal positioning of the cross slide. As the specific gravity of the plastic is about one-third less than that of aluminum, the wheels have less tendency to carry beyond a determined position. Collet chuck guards and various knobs and handles also are of plastic. Parts were developed by Eclipse Moulded Products company in conjunction with Gisholt engineers.





Multiple Pressures Measured

Aircraft engine tests require pressure measurements at multiple points remote from the observer. Simplification and weight reduction of the test equipment are attained, in the example illustrated, through the use of Automatic Switch solenoid-operated valves. A set of such valves, one for each pressure station, is mounted on a manifold having an outlet to a single pressure gage on the observer's panel. A multiple-contact manually-operated switch is used to energize the solenoid corresponding to the selected pressure point, opening that valve and connecting the desired point with the pressure gage.

Information about alloys...

GEARED

to industry's war needs

Converted to wartime tasks, American industry requires and calls upon us for information about alloys. Quickly available are practical answers to your questions about the selection, fabrication and uses of ferrous and non-ferrous materials containing Nickel. • Even before World War I, this Company pioneered studies of special alloys that provide added strength, toughness and wear-resistance. Our years of experience have been digested into printed reports and data sheets that help you save time and material. • Now, with all Nickel allocated where it may best speed Victory, our studies of alternative materials and processes become especially useful. • Upon request, personal assistance from our technical staff supplements the data in our printed bulletins.

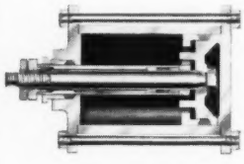
NICKEL

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK, N. Y.

PRECISION CYLINDER CONSTRUCTION *Pays Off in Better Performance*

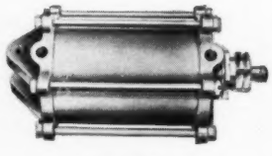
Honed bore of a 16 in. x 7 ft. cylinder

More useful work from air power—without leakage, with minimum friction loss, and simplest maintenance—are advantages directly resulting from Hannifin pneumatic cylinder design and construction. Hannifin Cylinders—in all sizes—are bored and then honed, producing a cylinder bore that is straight, round, and perfectly finished. The exclusive adjustable piston packing design makes use of soft, graphite-treated piston packing, adjustable from outside the cylinder. The efficient piston seal can be easily maintained throughout the entire life of the packing. In an emergency the piston can be repacked with standard graphited packing, always available. No special parts are required.



Sectional view

Hannifin pneumatic cylinders are built in a full range of standard mountings, sizes 1 to 16 inch bore, for any length stroke. Both single and double-acting types available, with or without air cushion.



Model B3

***New bulletin* gives complete specifications of Hannifin Pneumatic Cylinders and Air Control Valves. Request Bulletin No. 57-MD.**

HANNIFIN MANUFACTURING COMPANY
621-631 South Kolmar Avenue • Chicago, Illinois

HANNIFIN
PNEUMATIC CYLINDERS

Professional Viewpoints

" . . . on utilizing standard parts"

To the Editor:

I have just finished reading your July editorial on standard parts. It seems to me this could very well be expanded into an article of several pages length for it is an excellent idea.

—J. N. LANDIS
Consolidated Edison Co. of N. Y. Inc.

Thanks, Mr. Landis. More extensive coverage will be given in future issues.—ED.

" . . . authentic information"

To The Editor:

I want to compliment you on John Delmonte's article on impregnated plywood in the July issue of MACHINE DESIGN. Obviously Mr. Delmonte drew on sources of authentic information and also is qualified to write on so technical a subject.

There is one slight error in the caption to the Army boat hull, as only the two outer plies of this shell are resin-impregnated. However, this is a detail of manufacture and does not affect the general value of the article.

—L. H. MEYER
United States Plywood Corp.

" . . . availability of plastics"

To the Editor:

Considerable confusion has arisen in recent months on the availability of plastics materials for national defense and civilian purposes.

Demands for national defense have in some cases overtaxed the production capacities of materials manufacturers. This has been due to a shortage of certain raw materials, though the situation is changing all the time. For example, formaldehyde, which was rated as being critical six months ago, is now abundant. There is still a decided shortage of phenol. However, in recent weeks urea and melamine-formaldehyde resins have become more abundantly available. No doubt as new uses for these materials develop in the war program they, too, will be placed on the critical list.

Considering synthetic resins, the vinyl derivatives which contain chlorine and also the acrylics and the styrenes are very much in demand. Notwithstanding, a favorable situation exists in that applications of polyvinyl acetate and polyvinyl butyral are still possible. Recent restrictions upon the thermoplastics, of course, are curtailing excessive activities with these materials.

—JOHN DELMONTE, *Technical Director*
Plastics Industries Technical Institute

ZINC IN WAR

Zinc Coated Steel Cables for Barrage Balloons

ADEQUATE GALVANIZING REQUIRED

The standard for U. S. Army and Navy purchases is *the best available*—and that is as it should be. Not only do our fighting forces deserve the best in performance, but quality insures obtaining full value for every war dollar. Typical of this economy are those war applications of iron and steel which involve corrosion problems. In such cases, *adequate* galvanizing (zinc coating) is required—because scant galvanizing wastes zinc, time and money.

The U. S. Bureau of Standards (Circular 80) states that zinc is "by far the best" protective metallic coating for the rust-proofing of iron and steel. Because zinc is above iron in the electromotive series, corrosion will attack zinc first, thereby protecting the iron from rust. Even though iron or steel is exposed in small areas such as at cut edges, in a protective coating, it is not corroded—if that coating is zinc.

Galvanizing serves the war program in many ways. Illustrated above and below are the all-important *galvanized steel cables on a barrage balloon*, and a few other typical examples of war galvanizing are shown in the background of this page: (1) portable steel landing field, (2) corrugated iron bomb shelter, (3) merchant marine wire rope hoist, (4) wire netting for camouflage. Not illustrated is the all-important zinc-coated pipe on ships.

It is the job of the zinc industry to see that sufficient zinc is available to provide *adequate* galvanized coatings for all-important war applications. This is a major reason why civilian users of metal and pigment may not be able to obtain all of the zinc they would like to have.

THE NEW JERSEY ZINC COMPANY

MANUFACTURERS OF THE FAMOUS HORSE HEAD ZINC PRODUCTS

10 GALVANIZING

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2 RUBBER

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8 METAL SPRAYING

9 STAMPING DIES

FOR VICTORY

BUY UNITED STATES WAR SAVINGS BONDS STAMPS

War jobs demand
speed with accuracy
... Arkwright gives you both!

Those blueprints whirling through the machine must be sharp and clear – or else. Mistakes on war jobs can be as bad as sabotage – why risk them by using inferior tracing cloths? Arkwright's superb, uniform, closely-woven finish is your best protection. It assures perfect jobs – now and for years to come. Give your men this inexpensive aid to better work. Arkwright Finishing Company, Providence, Rhode Island.

Arkwright
TRACING CLOTH
AMERICA'S STANDARD FOR OVER 20 YEARS

ASSETS to a BOOKCASE

The Science and Practice of Welding

By A. C. Davies; published by the Cambridge University Press; 436 pages, 5¼ by 7¾ inches, clothbound, available through MACHINE DESIGN *for $2.25 postpaid.*

Importance of welding in the current war effort makes it imperative that the design engineer have more than a mere speaking acquaintance with the several welding processes in order that the speed and economy of welded fabrication may be used efficiently in his designs. This book should serve this purpose admirably. It is prepared from an intensely practical standpoint, although the relationship of the underlying sciences of physics, chemistry, metallurgy and electricity are thoroughly emphasized.

In addition to electric arc and oxyacetylene welding, detailed discussion is included of such other processes as metallic arc, hydrogen arc, resistance, flash and thermit welding. A chapter is also devoted to the oxyacetylene cutting of iron and steel. Economical and efficient methods of designing machine elements for welded fabrication are illustrated by numerous line drawings.

□ □ □

Higher Mathematics for Engineers and Physicists

By Ivan S. Sokolnikoff and Elizabeth S. Sokolnikoff; second revised edition, published by McGraw-Hill Book Co. Inc., New York; 587 pages, 6 by 9 inches, clothbound, available through MACHINE DESIGN *for $4.50 postpaid.*

Engineering analysis usually involves first a basic theory with simplifying assumptions, followed by mathematical formulation of the problem and solution of the resulting equations. Because the engineer is primarily concerned with problems requiring experience and judgment rather than mathematical skill, he may occasionally find himself handicapped through lack of that skill. Sometimes his engineering judgment is so good that he can go back and simplify his original theory until the resulting equations can be solved with the limited mathematical knowledge at his disposal. At other times over-simplification is impossible or yields erroneous results, and the engineer must then dig out for himself the necessary mathematical background. As a work of reference in such cases, the Sokolnikoffs' book will be found directly useful.

Familiarity with engineering college mathematics is assumed, and the reader should be warned that more than a superficial background

NOW it's aircraft engines where sedans "used to grow"... or plastics instead of critical metals... or welding replacing rivets. The man on the assembly line has *seen* the changes taking place—one after another.

One thing, though, hasn't changed—merely "changed over" to war production. In the Torrington Needle Bearing, veteran production men recognize an old familiar name. For this unique bearing is proving its adaptability anew, in applications where its advantages mean more today than ever.

Its ease of installation, for example, is cutting assembly time... enabling green hands to "catch on" more rapidly, experienced hands to work with the speed and efficiency war production schedules demand.

Every feature of the Needle Bearing, in fact, is filling some vital wartime need. Its small size is saving space and critical materials; its simplified design is eliminating extra parts and assembly steps; its low coefficient of friction, assuring smooth performance ... high capacity and efficient lubrication, reducing the need for replace ment or maintenance attention.

And so it is easy to understand why the Torrington Needle Bearing is in service today on new assembly lines all over America—assembly lines geared to production-for-Victory.

FOR INFORMATION *concerning capacities and sizes, send for Catalog No. 109. Or consult a Torrington engineer. He is an expert in adapting the Needle Bearing's unique advantages to specific problems.*

THE TORRINGTON COMPANY
TORRINGTON, CONN., U. S. A. • *Est. 1866*
Makers of Needle and Ball Bearings
New York Boston Philadelphia Detroit
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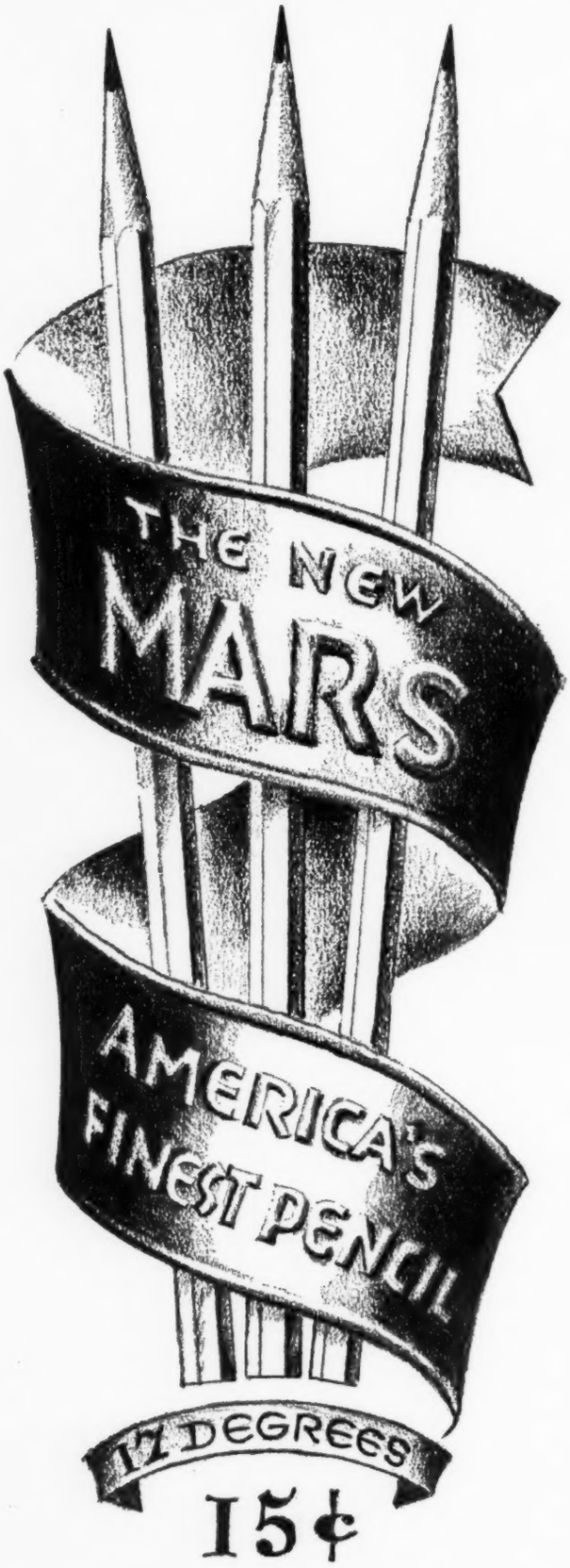
TORRINGTON NEEDLE BEARING
Every feature fills a wartime need



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NEW YORK

knowledge is required. Single chapters as far as possible are independent of the others and can be used without too much reference to other parts of the book.

As might be expected from the scope of the work indicated by the title, many of the topics considered are outside the range of interest of the designer, but the sections that apply in engineering analysis will be found to treat the subject in a practical manner. Chapters are included on infinite series, Fourier series, solution of equations, partial differentiation, multiple integrals, line integrals, differential equations (ordinary and partial), vector analysis, complex variable, probability and empirical formulas and curve fitting. In addition to examples worked out in the text, numerous problems are provided for practice in acquiring skill and confidence, with answers given at the end of the book.

□ □ □

Production Engineering

By Earle Buckingham, Professor of Mechanical Engineering, Massachusetts Institute of Technology; published by John Wiley and Sons Inc., New York; 268 pages, 6 by 9 inches, clothbound, available through MACHINE DESIGN *for $2.50 postpaid.*

Relationships between the many details of production engineering are not always clearly understood by engineers responsible for only a part of the general scheme of operations. Professor Buckingham succeeds admirably in his avowed purpose of presenting an assembly drawing of the subject to give each individual the proper perspective. Devoid of illustrations, tables or formulas, the book is one that can be read like a novel rather than consulted like a handbook.

Extended discussion is devoted to tolerances, metalworking processes and equipment, tool design, personnel problems including favoritism and graft, quality and cost controls, standardization, process and product development, and other topics. Clear distinction between functional design and design for production is emphasized throughout the book. Failure to recognize the separate nature of the two phases is often responsible for costly changes and delays in the earlier stages of production, and for widening the too-frequent rift between the manufacturing department and the engineering staff. Division of responsibility for the correction of troubles is a subject on which opinion is divided, and the author presents various viewpoints, showing how the solution in any particular case must be dictated by circumstances.

Clearly written, with commendable brevity, the book will be found stimulating alike to younger engineers who need perspective and to experienced men desiring a refresher course in this extensive subject.

You may be one of the many manufacturers or users of machines and equipment who would like to use a lot of Magnesium Alloy Products, but can't get them. Of course, you know the reason; airplanes and other combat materiel are taking every pound produced.

The properties of Magnesium that make it desirable for your use, its high strength-weight ratio, also make it indispensable for fighting equipment. That's the reason why American Magnesium plants are working day and night to produce more and more of these lightest of lightweight metal products.

When this war is won, there's going to be an abundance of Magnesium for peacetime products. Now's a good time to be thinking, therefore, "Where can we step up the tempo of our operations by using strong, light-weight Mazlo Magnesium Products?" Sales Agent: Aluminum Company of America, 1703 Gulf Building, Pittsburgh, Penna.

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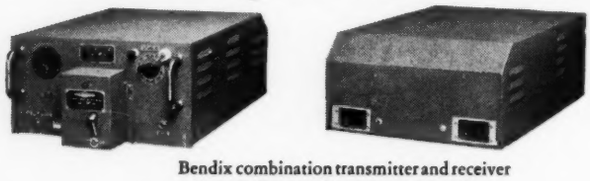
MAZLO MAGNESIUM PRODUCTS

Quick-change Artist
for rack equipment

The vital importance of radio in enabling ship and ground crews to maintain inter-communication and the necessity for quick, easy access for servicing and testing led to the development of the Cannon composite self-aligning connector for rack type "plug-in" equipment. Various units of the radio system must be hooked up and disconnected with a minimum of time and effort without disturbing the hundreds of small wires carrying essential circuits. Truly a "quick-change artist," the Cannon Connector illustrated above meets these requirements ideally. This is a typical application of one of the many types of Cannon Plugs designed for use wherever electrical connections must be made quickly and with absolute certainty.



Bendix combination transmitter and receiver with two Cannon Connectors for rack use.

CANNON ELECTRIC DEVELOPMENT COMPANY
LOS ANGELES, CALIFORNIA

Consider Glass in Meeting Materials Shortage

(*Concluded from Page* 89)

possible to be too careful in avoiding stress concentrations. Thus threads or keyways are out of the question where any appreciable load is involved in the attachment of glass parts to other materials. How the problem of attaching the glass impeller to the steel shaft of the Nash-Corning centrifugal pump was met is shown in *Fig.* 7. The impeller was molded with a ribbed surface inside the hub,—the hollow stub shaft which in effect is a bushing having a similar ribbed surface on the outside. With the two parts accurately located with respect to each other, typemetal, which expands slightly on solidifying, was injected into the space between the parts. Due to the use of dovetailed slots in the impeller, contraction during subsequent cooling increases the clamping action and insures a tight attachment. Another method of attaching glass to metal is to spray the glass surface with suitable metal and use solder for the attachment. With glass and metal having identical thermal expansion characteristics, direct sealing of the two materials is possible, and alloys have been developed for this purpose.

New Techniques Being Developed

Casting of glass parts is only possible where a very large mass is involved, best known example of which is the 200-inch telescope disk. Large ornamental pieces are cast in sculptured molds. The amount of detail possible is restricted by the high viscosity of the glass, but production methods using patterns for making the molds are a definite possibility. Future developments are also possible using powdered glass melted in the mold. Where clear transparency and smooth surface are not essential these methods may prove to be highly satisfactory.

Further developments in the use of glass in machinery depend on recognition by engineers of glass as a material with great potentialities, followed by close co-operation with glass companies in arriving at suitable designs which can be economically manufactured. New technique in glass manufacture and molding are being developed and many of the present limitations of glass will undoubtedly disappear.

Co-operation of the following companies in supplying information and illustrations included in this article is acknowledged with appreciation: Consolidated Lamp & Glass Co.; Corning Glass Works, *Figs.* 2, 4, 5 and 6; Fish-Schurman Corp.; Libbey-Owens-Ford Glass Co.; Nash Engineering Co., *Fig.* 1; Owens-Corning Fiberglas Corp., *Fig.* 3; Pennsylvania Wire Glass Co.; Pittsburgh Plate Glass Co.; and Safetee Glass Co. • The generous assistance of Corning Glass Works was particularly noteworthy.

This New Tracing Cloth Prevents Scars and Stains on your Drawings

PHOENIX is an improved tracing cloth that defies perspiration stains and water marks—*that holds pencil smudges and erasure scars at a minimum.* Now you can have clean tracings, in pencil or ink, free from the untidy "ghosts" that reproduce on blueprints!

For PHOENIX is ghost-proofed by a remarkable new process that defies moisture, and gives you an unusually durable working surface. You can use harder pencils with this improved cloth and get sharper lines with less tendency to smudge. Even 6H pencil lines show clearly, and reproduce sharply! Erasing does not mar the drawing surface; erased areas take pencil smoothly —and ink without feathering. The new white color and increased transparency provide excellent drawing contrast and produce strong blueprints.

Let PHOENIX prove its merits on your own drawing board. See your K&E dealer, or write for a generous working sample and an illustrated brochure.

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TRACING CLOTH

for pencil *and* ink

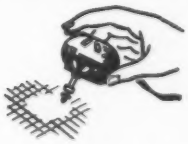
PHOENIX DEFIES MOISTURE GHOSTS

Perspiration and water splashes on ordinary tracing cloth create "ghosts" which reproduce on blueprints. PHOENIX Tracing Cloth withstands actual immersion in water for fully 10 minutes at a time! *Perspiration and water marks will not stain it!*

PHOENIX LESSENS SMUDGE GHOSTS

The new improved surface of PHOENIX Tracing Cloth permits you to use harder pencils (5H and 6H) and to get sharper lines with less tendency to smudge.

Result: Cleaner tracings and blueprints.



PHOENIX REDUCES ERASURE GHOSTS

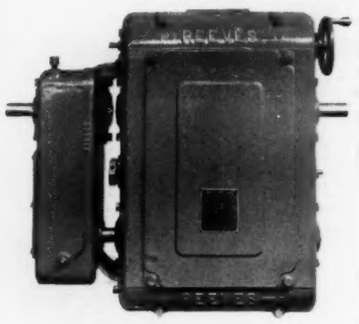
Ordinary tracing cloths become scarred when erased... erased spots produce ghosts on blueprints.

PHOENIX has a durable drawing surface that reduces working scars to a minimum.

New PARTS AND MATERIALS

Built-in Chain Drive Reducer

OF SPECIAL design, a new variable speed transmission for attachment to machines is being offered by Reeves Pulley Co., Columbus, Ind. It is of enclosed design, equipped with built-in chain reducer, and with the output shaft in exact alignment with the input shaft. Output speeds are in-



finitely variable, within predetermined limits, by turning speed control handwheel. Chain drive operates in a bath of oil. The unit illustrated was designed for vertical operation with oil drain and filler located accordingly.

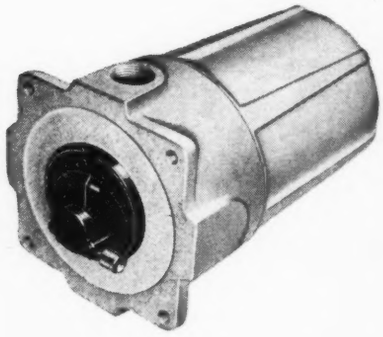
Lightweight Limit Switch

DESIGNED specially for aircraft applications, General Electric Co., Schenectady, N. Y., has introduced its new lightweight limit switch. Contact mechanism used is the company's switchette.

Snap action and double-break operation give the switch a high current rating. Plunger operates with a 7/32-inch overtravel, which increases the number of applications for which the switch can be used. The aluminum housing is made dustproof by use of gasketed cover, and adequate space is provided inside housing for easy wiring. Available in three contact arrangements—single-circuit, normally open or normally closed, and single-pole, double-throw—the switch in each form can be furnished with a contact air gap of .01, .02 or .03-inch. Weight is .13-pound.

Explosion-Proof Timers

EXPLOSION-PROOF timers suitable for operations in atmospheres containing gasoline, naphtha, petroleum, benzol, acetone, lacquer solvent, natural gas, etc., are being offered by The R. W. Cramer Co. Inc., Centerbook, Conn., to meet the many present-day demands. In the accom-



panying illustration is shown a Type TD1C explosion-proof time delay relay laid out for panel board mounting with setting knob and dial projecting. It is feasible to mount either a TD1c or TD1 with a small relay within this housing. The latter construction would be used where it is desired to control the timer from a remote momentary start button.

Electric Hydraulic Power Unit

RECENTLY introduced by Logansport Machine Inc., Logansport, Ind., is a new electric-hydraulic power unit, particularly for hydraulic chucking installations on machine tools but also adaptable to other applications. This new model 5036 hydraulic power unit is not only capable of operating additional cylinders for tailstock or similar requirements but it also sustains the pressure during different executions of the work cycle. Maintain-

ACCURATE CORES··

Speed Production of Precision Castings

Speed is all important these days . . . but so is accuracy. You'll get *both* in cored castings by National.

1. Special formulas for core sand and core spray have been developed over a period of 30 years to take care of each individual requirement.
2. Skilled foundrymen mix these formulas under laboratory control in machines designed especially for this purpose.
3. Production cores are "blown" and core dryers used whenever possible to insure accuracy and increase production.
4. Cores are baked properly in the latest type of thermostatically controlled ovens, insuring cores of proper texture for every different type of casting.

National's skilled men, expert supervision, good materials, modern machinery, give you accurate cores which speed the production of precision castings.

THE NATIONAL BRONZE AND ALUMINUM FOUNDRY CO.

Twin Plants — Cleveland, Ohio

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DESIGN HYDRAULIC MACHINES THIS FAST... SIMPLE WAY

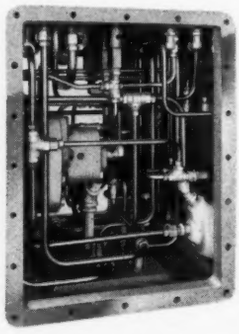
Barnes self-contained hydraulic unit complete with tank, motor, pumps and valves for operating two independent traversing and clamping circuits, and one traverse circuit of wheel spoke forging machine.

Use Unit-Type Hydraulic Structures for New Designs

These self-contained hydraulic units are designed to meet specific machine requirements. They are complete with pumps, pump-controls, valves, and oil reservoir. All piping, except to cylinders, is compact and included in the unit.

Save Design Time...Speed Delivery

Units can be designed and built for control of elements or functions of Milling, Boring, Grinding, Drilling and other metal working machines. They can also be furnished for operations of other types of machines whose functions can be controlled to better advantage hydraulically. *This hydraulic designing can be done simultaneously with your machine designing.* When your machine is ready for assembly you will have a complete hydraulic unit easy to mount, and designed to meet the needs of your machine — piping each machine cylinder constitutes your total hydraulic effort.



Compact Hydraulic piping eliminates unsightly exterior piping. Circuit is complete, and tested for immediate installation.

For Complex and Simple Circuits These standard hydraulic units are in use in mass production machine tools in all of our prominent automotive plants, in simple and complicated machining cycles. For additional data write for the booklet offered below.

FREE New Data: Included in this 40 page book are typical installation circuits, complete data covering piston and gear pumps and complete information covering basic elements of construction and installation of standard units used in these highly successful hydraulic circuits. Write for your copy today. Ask for Bulletin M.D. 842.

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MAIN OFFICE AND FACTORY
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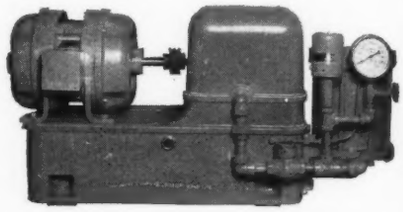
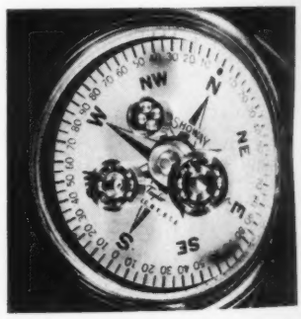
ing of this pressure without electric motor running constantly is permitted by a spring-loaded accumulator. Electric motor is automatically shut off by a built-in standard pressure switch of a nondiaphragm type when accumulator has been charged to 550 pounds per square inch, and remains off



during the greater part of the machine operation. Capacities of the unit are: Pump delivery, 8 gallons per minute; pressure range, 550 pounds per square inch maximum to 450 pounds per square inch minimum; electric motor requirements, 3 horsepower, at 1200 revolutions per minute, NEMA frame, No. 254; and oil capacity of tank, approximately 15 gallons.

Nonmagnetic Bearings Available

DESIGNATED as NM4, NM5 and NM3P, representing Nos. 4 and 5 radial bearings and No. 3P pivot bearings in the nonmagnetic series, the latest additions to the line of miniature precision bearings manufactured by Miniature Precision Bearings, Keene, N. H., have many applications. Some of these uses are where a magnetic bearing would introduce instrument variations, to avoid electrical conductivity, and to resist salt spray vapor or other mild corrosives. Races and balls in this series are beryllium copper alloy, hardened after machining by heat-treatment to approximately 40 rockwell. All dimensions and tolerances are the same as the company's SAE 52100 chrome steel bearings.

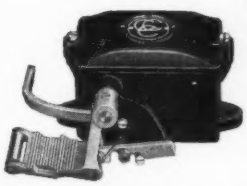


Transparent Temporary Coating

FOR metal and ceramic surfaces to reduce rejects due to rust, surface scratches, shop wearing, grease and dirt, a new protective coating has been announced by Ault & Wiborg Corp., Cincinnati. Known as Protektol, the material is completely transparent to permit visual inspection of the coated parts. Having a plastic base, it is applicable to highly polished surfaces such as flat sheets, molds, irregular shapes, dies and bearings, offering protection during handling, fabrication,

TYPE FSL 11, FSL 22, FSL 33
FOOT SWITCH WITH LATCH

TYPE FWS 22
WITH STOP FOOT SWITCH



TYPE FWLS 22 LATCHING
POSITIONED FOOT SWITCH

TYPE FRS 22 DOUBLE
PEDAL FOOT SWITCH

TYPE FS 44
4 POLE FOOT SWITCH

As part of the "3C" share toward "V for Victory", the above Bulletin 101 Heavy Duty Foot Operated Master Switches are offered for Mill and Industrial Service.

Furnished with or without latch, Right or Left Pedal, Dust Tight (NEMA IC 50-28), Water Tight (NEMA IC50-43) with Moving Finger Mechanism interchangeable on all Types, these switches are adaptable to a wide variety of applications.

In hundreds of plants engaged in production of Defense materiel, "3C" Foot Switches are providing dependable low-maintenance Service. A fully descriptive Bulletin 101 is yours for the asking.

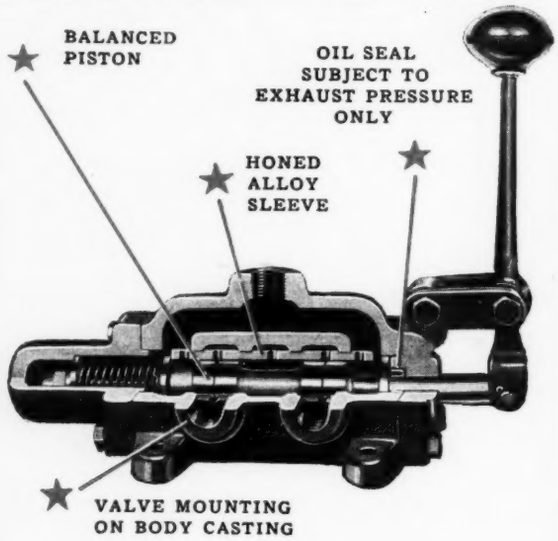
CONTINUE TO ROLL WITH CLARK CONTROL

THE CLARK CONTROLLER CO.

1146 EAST 152ND ST. CLEVELAND, OHIO

with

RACINE 4 WAY VALVES



RACINE balanced piston, sleeve type valves embody the latest developments in modern hydraulic design. Their soundly engineered, rugged construction insures positive performance and long trouble free service.

RACINE valves provide for complete hydraulic balancing of all interior moving parts. Honed alloy sleeve supports piston on a continuous bearing surface. Multiple drilled porting holes in the valve sleeve reduces shock by tapering off volume when oil flow direction is changed. Oil seals are subject to exhaust pressures only for longer life and less leakage. Valve mounting feed are part of the main body casting so that gaskets and seals do not absorb pipe line vibrations.

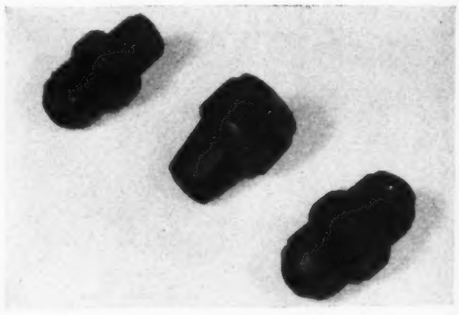
Write for our new catalog P-10-C giving complete details. Our engineers will be glad to work with you and to show how RACINE Variable Volume Pumps and Hydraulic Valves can be readily designed into your equipment.

RACINE TOOL & MACHINE CO.
1773 STATE ST. RACINE, WIS.

shipping, storage and installation. The liquid is sprayed, brushed, dipped or roller coated; then air dried to leave a flexible glass-clear coating of from .001 to .0015 inch. Drying time at 200 degrees Fahr. is six to eight minutes. The degree of adhesion of the coating to the part protected is controlled to eliminate possibility of accidental or premature removal. The coating is not affected by most greases and oils, is water and sunproof, and does not deteriorate or crack at temperatures between zero and 200 degrees Fahr. It is available in colors making an ideal temporary identification medium. After coating has been removed from the part, it may be returned and reduced to liquid form for repeated use.

Molded Nonmetallic Fittings

NOW available are fittings molded from Saran for tubing sizes ⅛-inch to ⅜-inch outside diameter, through Acadia Synthetic Products division of the Western Felt Works, 4115 Ogden avenue, Chicago. By the use of these fittings it is possible to set up a complete chemically-resistant

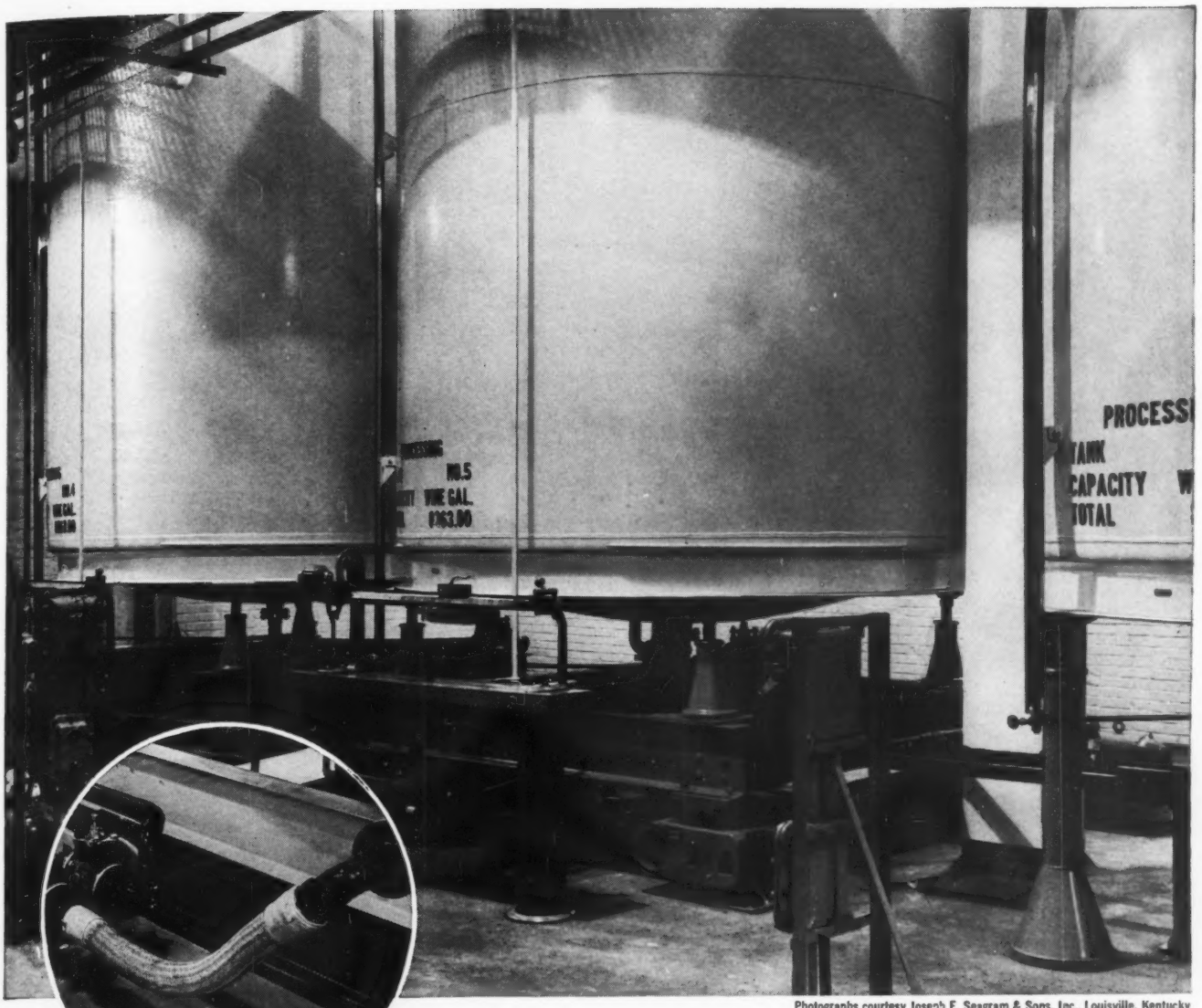


piping system without metal, thus breaking the bottleneck of availability of materials for this purpose. Having a high tensile and bursting strength, the fittings are noncorrosive and nonaging and, being also nonconductors of electricity, are able to prevent the formation of galvanic couples. The company also processes Saran tubing, pipe, rod and sheet.

Light Midget Switch Introduced

MEETING a need for an extremely light and small switch, The Acro Electric Co., 3179 Fulton road, Cleveland, has placed on the market its new Midget which retains all the features and advantages of the standard switch offered by the company, including the unique principle of the rolling spring which snaps the blade from one position to another. This rolling spring construction calls for only a few parts and very low operating strain. In the open model the actuating pin protrudes from the bottom of the switch, while in the enclosed one it is mounted either in the cover or the bottom. The size of the new switch is 1½ x 21/32 x 7/16, with a weight of 7¼ grams. With a cover which

(*Continued on Page* 118)



Photographs courtesy Joseph E. Seagram & Sons, Inc., Louisville, Kentucky

There's a twist to measuring spirits in 8,000 gallon "jiggers"

American Seamless conveys alcohol safely . . . provides compensating flexibility . . . for delicate task on scale tanks at Seagram's Louisville Distillery.

The giant distillery business of this country has undergone a "conversion" too . . . making alcohol for smokeless powder production. And in this, as in other vital war industries, dependable American Seamless Flexible Metal Tubing is helping to do a better job.

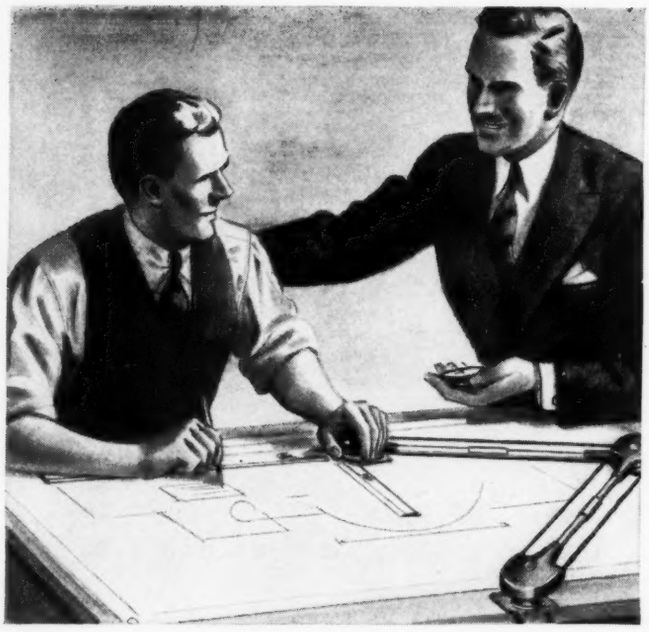
In this case, American Seamless, with its "garden hose" flexibility, compensates for the vertical twist that takes place with weight changes on these large "scale tanks". At the same time, its tinned bronze interior provides non-toxic contact with the alcohol.

As always American Seamless and other products of American Metal Hose are serving wherever industry needs dependable flexible connectors for conveying steam, air, oil and other liquids and gases. Today, of course, our entire output is serving the war program, and it will doubtless continue to do so until peace is won. 42197

ANACONDA

American Metal Hose

AMERICAN METAL HOSE BRANCH of THE AMERICAN BRASS COMPANY • General Offices: Waterbury, Conn.
Subsidiary of Anaconda Copper Mining Company • In Canada: Anaconda American Brass Ltd., New Toronto, Ontario



Saving minutes and hours for production's "Minute Men"

A BIG SHARE of tomorrow's Victory is being won on the drafting boards of the nation *today*. Here is where Bruning Rival tracing cloth gives *your* draftsmen maximum help in speeding their work—and in speeding production all along the line. Why? Because Bruning Rival has a superior and lasting transparency—not obtained with oils or wax. That means no guesswork—fewer errors—in tracing. Because Rival is easier to erase—no lost time trying to eliminate "ghosts." Because Rival has just the right surface "tooth" and texture. Because Rival is durable—with a high tensile strength that stands the hard test of use and handling.

Talk to a Bruning representative about Bruning Rival Tracing Cloth. No better tracing cloth. Charles Bruning Co., Inc.

2068-259

BRUNING

Since 1897

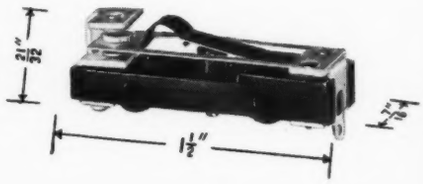
NEW YORK • CHICAGO • LOS ANGELES

Branches in 14 Principal Cities

SPEEDS—SIMPLIFIES—AND PROTECTS A NATION'S DRAFTING

(*Continued from Page* 112)

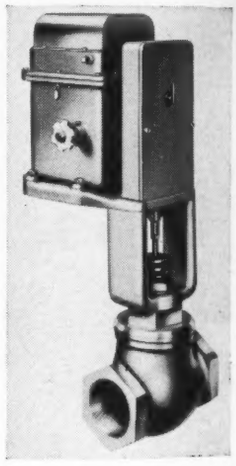
can be supplied if needed, weight is slightly over 8 grams. Gap is .04-inch. Actuating movement is .009-inch, actuating pressure 2½ ounces or less. The switch has ratings of 250 volts 5 amperes, and



115 volts 10 amperes, alternating current. It is applicable to tank, aircraft, gun turret and photographic uses and for many installations where the standard model cannot be used.

Motor-Operated Control Valve

FOR controlling of steam, water, oil or gas in air conditioning systems, dryers and industrial process work where close regulation is required. Barber-Colman Co., Rockford, Ill., is offering its new Microvalve which consists of a Microtrol unit and an eccentric cam that operates valve plunger. Valve sizes are available for almost all standard applications in above-mentioned categories and in similar installations. Single seat V-ported, double seat V-ported, and double seat 3-way valve bodies are available. The valve has proportioning type operator and is motor-driven.



Indicator Reports Circuit Break

VALUE and dependability of the indicator of Littlefuse Inc., 4757 Ravenswood avenue, Chicago, is evidenced by its wide use in railway signaling equipment and aircraft applications.

Known as panel mounting No. 1414, it is equally applicable to any circuit, circuit breaker, line switch, etc. When installed in connection with remote motor control it works instantly with a plainly visible signal to show "on" or "off". The indicator

Ohio Gear

PRECISION CUTTING solves problem of accuracy at low cost for RIDGE TOOL COMPANY

THIS ring gauge controls the work holders of the RIDGID No. 65R pipe threader. A simple turn adjusts them to required size. The scroll or series of concentric slots shown on the underside of the ring provides the method of adjustment. Accuracy, plus high resistance to wear, strain and shock are, of course, prime essentials in the part.

Formerly die-cast, with the slots as an integral part, the ring was changed to a forging to insure more wear resistance and longer life. Use of the forging required that the slots be machine cut, presenting the problem of obtaining these cuts *at a cost somewhat comparable to that of die-casting.*

Cutting these slots regardless of cost offers no difficulty. OHIO GEAR COMPANY, however, solved the entire problem of accurate *cuts at required low cost* through the use of standard gear cutting equipment. Thus, another example of the many ways OHIO GEAR COMPANY engineering skill and manufacturing experience are meeting today's gear problems in industry.

THE OHIO GEAR CO.
1338 E. 79th Street • Cleveland, Ohio

★ ★ ★

*NEW YORK CITY, N. Y.
Patron Transmission Co.
154-156 Grand Street

NEW ENGLAND
George G. Pragst
332 Main St., Pawtucket, R. I.

*LOS ANGELES, CALIF.
J. W. Minder Chain & Gear Co.
927 Santa Fe Avenue

GRAND RAPIDS, MICH.
W. H. Slaughter
1924 Madison Ave., S. E.

*PITTSBURGH, PA.
Standard Machinists Supply Co.
South 2nd and McKean Street

DETROIT, MICH.
George P. Coulter
322 Curtiss Building

**Stocks carried.*

*MINNEAPOLIS, MINN.
Industrial Supply Co.
717 S. Eighth Street

BUFFALO, N. Y.
F. E. Allen, 2665 Main St.

*KANSAS CITY, MO.
Kansas City Rubber & Belting Co.
712 Delaware Street

*SAN FRANCISCO, CALIF.
Adam-Hill Co.
244-246 Ninth St.

LOUISVILLE, KY.
Alfred Halliday, 330 Starks Bldg.

*INDIANAPOLIS, IND.
A. R. Young
715 Fort Wayne Avenue

ST. LOUIS, MO.
St. Louis Tool Co.
2319 N. Ninth Street

★ ★ ★

OHIO GEARS

a VITAL FACTOR in the battle for production

• SPEED ADJUSTABILITY

Regulate the speed of your machines by the simple turn of a Lewellen handwheel *without stopping the machine*. Have the *right speed at the right time!*

• PRODUCT UNIFORMITY

Actually the lack of uniformity in materials and varying conditions in plants demand speed adjustability of production machines for uniform, quality work.

• MINIMUM SPOILAGE

Adjust machine speeds to equal the skill of operators—change in materials, and costly rejects are reduced to a minimum.

• MAXIMUM MACHINE OUTPUT

Check the rated capacities of your machines with actual production output. Often what a machine can do is simply a matter of its operation at the correct speed.

• UNINTERRUPTED SERVICE

Avoid the waste of time to change belts and gears. Keep production flowing smoothly.

• FACTORY SPACE SAVED

Lewellen Variable Speed Transmissions and Motor Pulleys are compact—modern in design. Often valuable space is saved by their use.

● This is no time to allow fixed-speed machines to bottleneck your production! Important advantages of Lewellen Variable Speed Control are listed above. Consider these advantages with respect to your production. Think of accurately maintaining speeds even to a fraction of an r.p.m. . . . We have no other interests than to help you solve your speed control problems. Now that these problems are so vital, we urge you to let us help you. No obligation.

LEWELLEN MANUFACTURING COMPANY, COLUMBUS, INDIANA

LEWELLEN

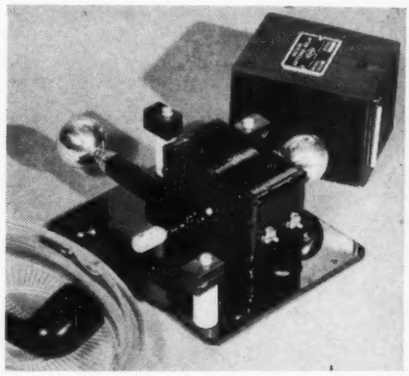
Variable Speed } **TRANSMISSIONS MOTOR PULLEYS**

★ **Lewellen knows speed control**

may be had for 24 or 48-volt filament bulb, with which no resistor is used; otherwise it uses a built-in 200,000 ohm protective resistor in series with a neon lamp. Resistor prevents lamp blowing out on unexpected high voltages. The body is black bakelite and the cap molded transparent materials. It is made for panels up to 5/16-inch thick and ¼-inch diameter mounting hole. Overall length is 2 inches below panel and ⅞-inch above panel. Rating is 90 to 250 volts.

Vacuum Relay Announced

MADE by Bendix Aviation Ltd., 11700 Sherman Way, North Hollywood, Calif., a new, small, lightweight antenna switching relay can handle radio frequency potentials of 20,000 volts at 30,000



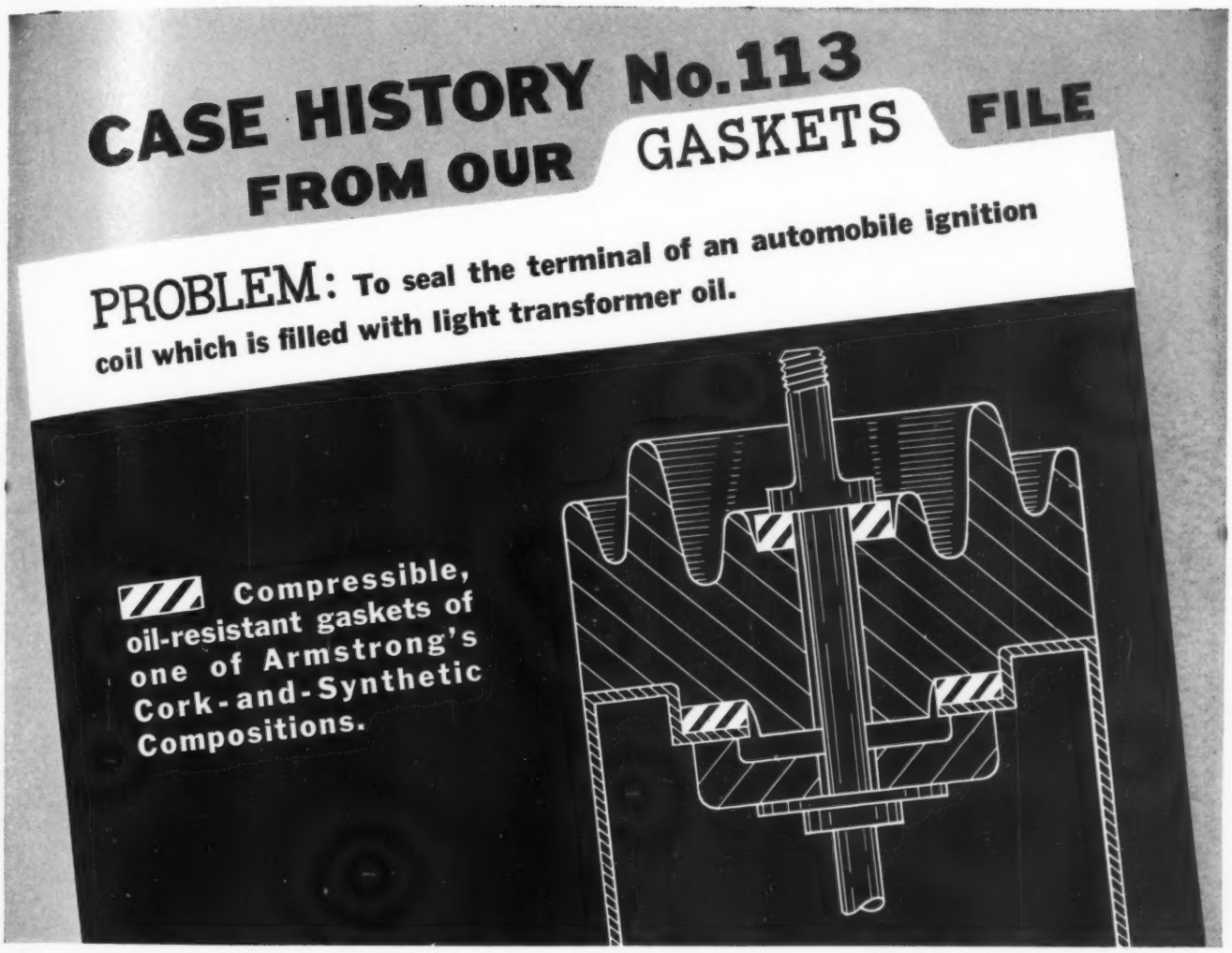
feet altitude. It consists of a single-pole, double-throw switch enclosed in highly evacuated glass envelope. When actuated by external electromagnet, armature transfers the circuit from receiver to transmitter. As space between open contacts is approximately .015-inch and because of small mass of armature, transfer is reported to be fast enough for instantaneous break-in. This speed enables keying at 40 words per minute. Fixed contacts are enclosed in high vacuum and operate independently of climatic conditions, dirt, altitude, or oxidation. Weight of relay is 24 ounces, including case, and size is 2⅝ x 5⅝ x 6 7/16 inches overall. Coils can be supplied for any of the common voltages and these are capable of continuous operation.

Relief Valve for Aircraft

FOR aircraft hydraulic systems a new noiseless relief valve has been announced by Adel Precision Products Corp., Burbank, Calif. Manufactured to conform with A. C. Specifications 27993, the valve through a radical design improvement is extremely quiet in operation—no screeches, screams or whistling sounds. Another feature is its consistently positive action at any adjusted setting. Simple in design, internal parts follow the company's basic practice as far as corrosion resistance and precision in manufacture are concerned. Weight is kept at a minimum by a permanent mold 356 aluminum alloy body. With

CASE HISTORY No. 113 FROM OUR GASKETS FILE

PROBLEM: To seal the terminal of an automobile ignition coil which is filled with light transformer oil.



A LEADING manufacturer of ignition coils for automobile engines decided to increase the life and efficiency of his product by filling it with light transformer oil instead of the customary pitch filler. The assembly at the terminal end of the coil called for two gaskets to serve as oil seals between the porcelain and metal parts. These gaskets had to be (1) compressible to avoid cracking the porcelain; (2) nonflowing under pressure—since neither gasket would be totally confined in assembly; (3) resilient to maintain permanently tight joints; (4) impervious to the oil and not subject to attack by it; (5) stable under varying temperatures due to weather and to heat from the engine.

SOLUTION

The manufacturer called in an Armstrong sealing specialist—who studied the requirements and recommended one of Armstrong's cork-and-synthetic compositions for the job. Due to the cork content, gaskets of this material compress without side flow. The synthetic content, as well as the cork, is oil-resistant and is unaffected by the temperatures involved. The gaskets retain their resilience permanently. The manufacturer has since used hundreds of thousands of these Armstrong Gaskets to seal the terminal end of oil-filled ignition coils and reports trouble-free performance.

ARMSTRONG'S SEALING SERVICE

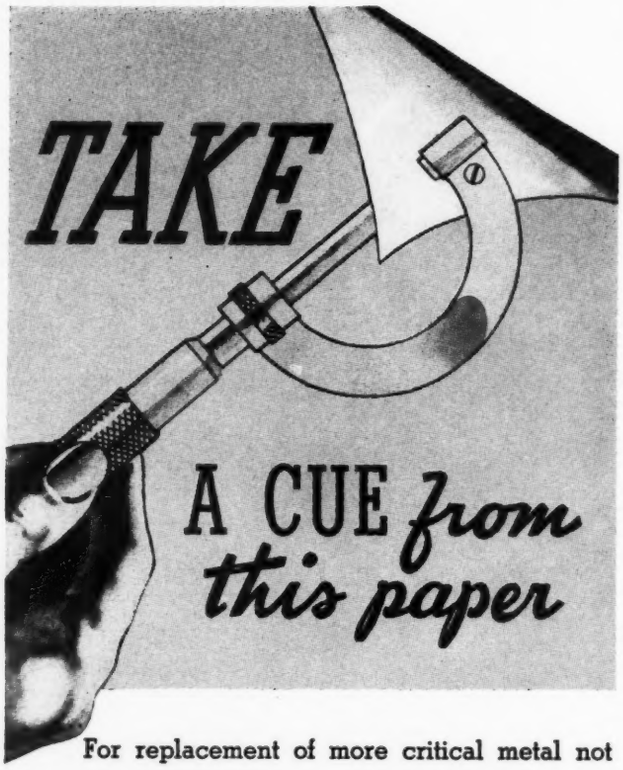
In addition to more than two dozen synthetic, cork-and-synthetic, and cork-and-rubber compositions, the Armstrong Line includes many different cork compositions . . . and No. 841 Fibrated Leather, a general-purpose gasket material offering the advantages of natural leather in large, uniform, low-cost rolls and sheets.

Armstrong compositions having virtually any desired physical properties are available in sheets, cut gaskets, molded or extruded shapes. An Armstrong representative will be glad to analyze your sealing requirements and submit samples of materials which meet them exactly. Write Armstrong Cork Company, Industrial Division, 942 Arch Street, Lancaster, Pa.

ARMSTRONG'S
GASKETS · SEALS
PACKINGS

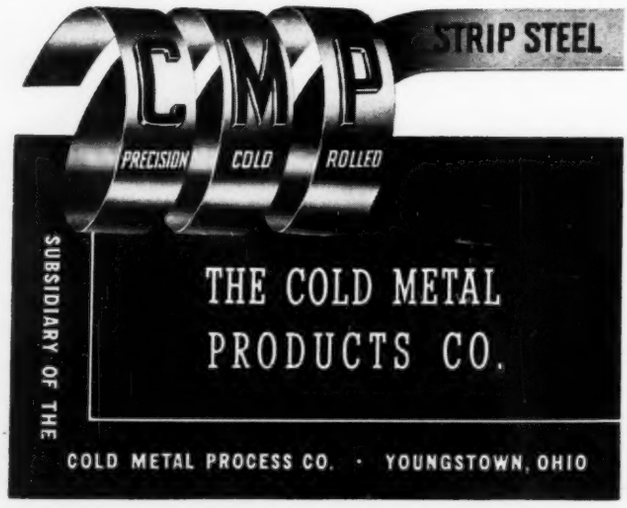
Cork Compositions
*Cork-and-Synthetics • Synthetics
Cork-and-Rubber • Fibrated Leather

*FORMERLY "CORPRENE"

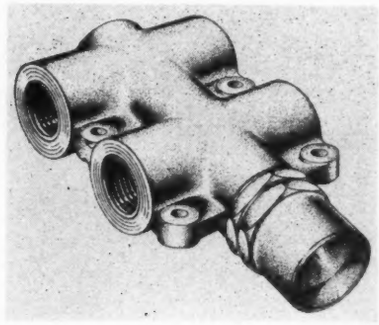


For replacement of more critical metal not now available because of the War Program, this might be your answer. Cold Rolled Strip Steel in paper-thin sizes is serving successfully in many important products. Other applications, involving a wide range of physical properties, are now developing. We have available information based on actual production data which might be helpful in solving other demands for light gauge metal.

An inquiry will bring helpful facts and cooperation to demonstrate the wide application and practical uses of Cold Metal Precision Light Gauge Strip Steel.



pressure ranges from 600 pounds per square inch to 2200 pounds per square inch as governed by specifications, the new valve is manufactured in sizes A-4 at 1 gallon, A-6 at 3½ gallons, A-8 at 5 gallons, and A-10 at 8 gallons per minute. Port



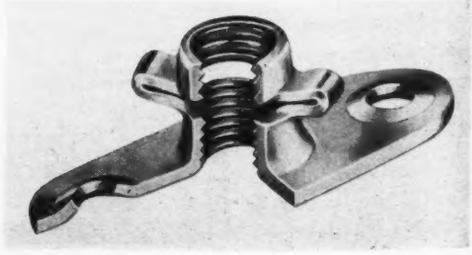
sizes, threads and fittings can be obtained in either AN 10050 specifications with synthetic rubber seals or AC 27993 specifications with serrated port end crush seals.

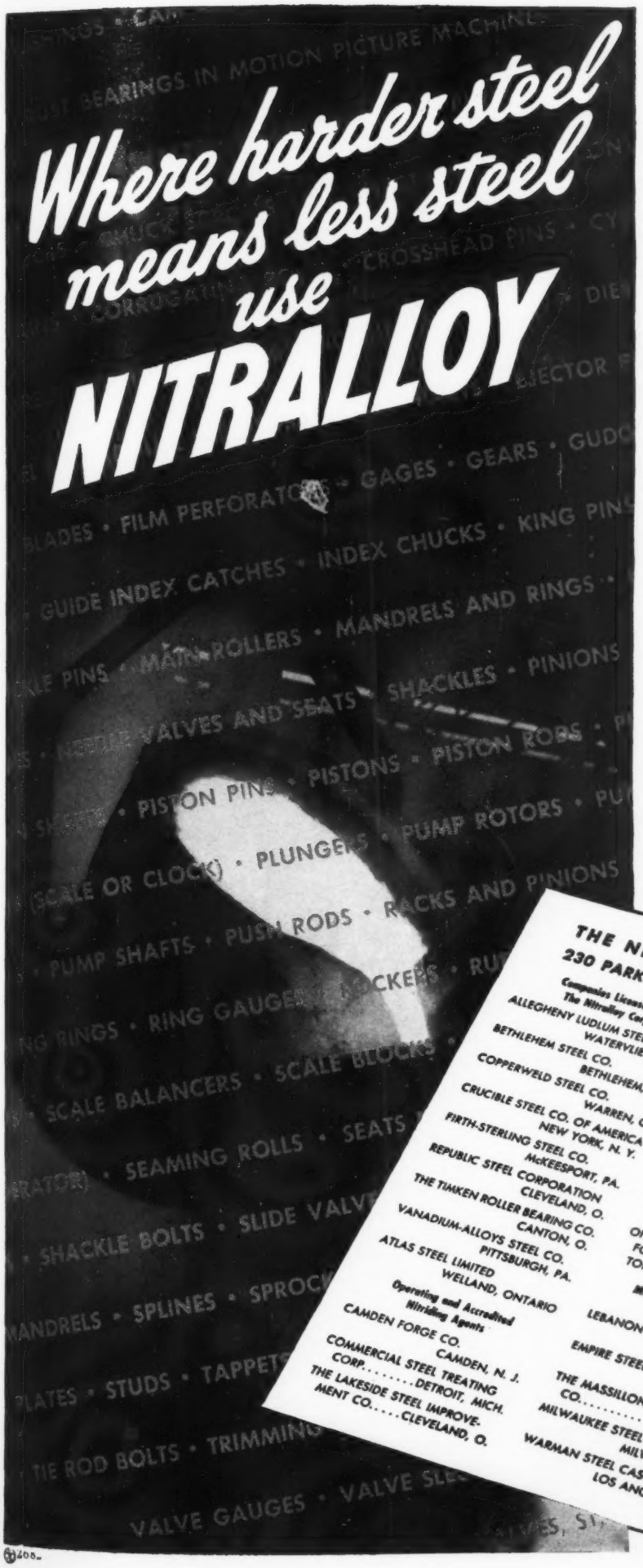
Substitute Alloy Steels

NATIONAL Emergency (NE) alloys, developed by the metallurgical staff of War Production Board to conserve nickel, chromium, vanadium and other needed metals, are available to manufacturers in small quantities for treating and testing in specific applications. Initial stocks will consist of six analyses: Carburizing alloys, NE 4023 and NE 8620; medium hardening alloys, NE 4042 and NE 8744; and high hardening alloys, NE 4047 and NE 8749. These analyses will be in form of hot-rolled rounds in size range from ½ to 7 inches in diameter. Specific data on performance of these steels is lacking and users are urged to report details of each operation, such as forging, machining, heat treatment response, as well as results of any other tests, so that this information can be made available to others. The steels are available from Joseph T. Ryerson & Son Inc., Sixteenth and Rockwell streets, Chicago.

Dimpled Rivet Holes

MACHINE-DIMPLED rivet holes are now embodied in the entire self-locking anchor nut line of Boots Aircraft Nut Corp., New Canaan, Conn. There is need for flush rivet mountings and




Where harder steel means less steel use
NITRALLOY
BEARINGS IN MOTION PICTURE MACHINE
CROSSHEAD PINS
BLADES • FILM PERFORATORS • GAGES • GEARS
GUIDE INDEX CATCHES • INDEX CHUCKS • KING PINS
MAIN ROLLERS • MANDRELS AND RINGS
VALVES AND SEATS • SHACKLES • PINIONS
PISTON PINS • PISTONS • PISTON RODS
(SCALE OR CLOCK) • PLUNGERS • PUMP ROTORS
PUMP SHAFTS • PUSH RODS • RACKS AND PINIONS
RING GAUGES
SCALE BALANCERS • SCALE BLOCKS
SEAMING ROLLS • SEATS
SHACKLE BOLTS • SLIDE VALVES
MANDRELS • SPLINES • SPROCKETS
PLATES • STUDS • TAPPETS
TIE ROD BOLTS • TRIMMING
VALVE GAUGES • VALVE SLEEVES
THE NITRALLOY CORPORATION
230 PARK AVENUE • NEW YORK, N. Y.
Companies Licensed by The Nitralloy Corp.
ALLEGHENY LUDLUM STEEL CORP. WATERVLIET, N. Y.
BETHLEHEM STEEL CO. BETHLEHEM, PA.
COPPERWELD STEEL CO. WARREN, O.
CRUCIBLE STEEL CO. OF AMERICA NEW YORK, N. Y.
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REPUBLIC STEEL CORPORATION CLEVELAND, O.
THE TIMKEN ROLLER BEARING CO. CANTON, O.
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THE LAKESIDE STEEL IMPROVEMENT CO. CLEVELAND, O.
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LINK-BELT CO., PHILADELPHIA, PA.
MET-LAB, INC., PHILADELPHIA, PA.
NEW ENGLAND METALLURGICAL CORP. BOSTON, MASS.
PITTSBURGH COMMERCIAL HEAT TREATING CO. PITTSBURGH, PA.
QUEEN CITY STEEL TREATING CO. CINCINNATI, O.
WESLEY STEEL TREATING CO. MILWAUKEE, WIS.
ONTARIO RESEARCH FOUNDATION TORONTO, ONTARIO, CANADA
Manufacturers of Nitralloy Steel Castings
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MILWAUKEE STEEL FOUNDRY CO. MILWAUKEE, WIS.
WARMAN STEEL CASTING CO. LOS ANGELES, CAL.

NITRALLOY, alloy-steel, produces the hardest steel surface known. By prolonging the life of vital machinery parts subject to wear, fatigue and abrasion, NITRALLOY conserves steel, alloys, labor, shop capacity, transportation, fuel and power.

In defense work, NITRALLOY and the Nitriding Process contribute to the effectiveness and stamina of planes, tanks, trucks, artillery, and marine equipment—as well as of the machine tools needed to produce this war equipment.

A Typical* NITRALLOY *Analysis

CARBON	**0.35**
MANGANESE	**0.50**
SILICON	**0.30**
CHROMIUM	**1.00**
ALUMINUM	**1.00**
MOLYBDENUM	**0.25**

Nitrided NITRALLOY parts can be produced with case hardness exceeding 1000 Vickers-Brinell, and core hardness of more than 300 Brinell, with ultimate strengths up to 190,000 lbs. per sq. in. Within wide limits, strength and hardness of core are variable by correct selection of composition and heat-treating temperature.

NITRALLOY metallurgists welcome consultation and opportunities to recommend the most suitable composition and treatment for any given purpose. The NITRALLOY Data Book will be useful in considering possible applications. Copies are available on request to us or our licensees.

NITRIDING

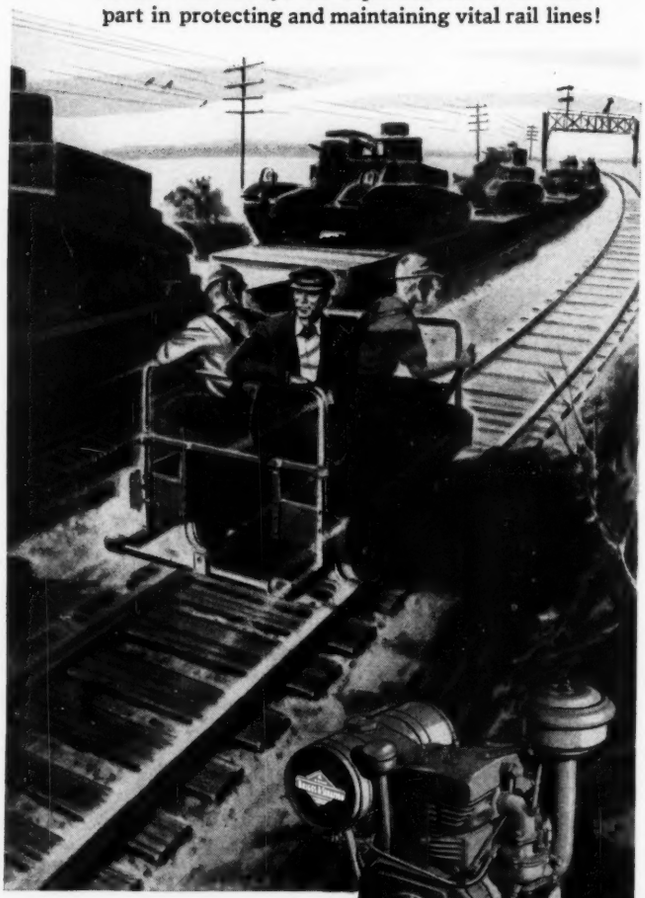
is the process of case hardening certain alloy steels by means of a nitrogenous medium, such as ammonia gas. The alloy steels that are most suitable for Nitriding are known as

NITRALLOY

SMALL MOTORS ON PATROL—

Guarding America's Railways

Shipments of war material must have the "green light." Roadbeds need inspection and maintenance — bridges, railheads, and war shipments must be protected against saboteurs, wear and tear. So old-fashioned handcars and maintenance equipment give way to modern railroad machinery powered by Briggs & Stratton 4-cycle, air-cooled gasoline motors. These sturdy, easy-starting motors can always be depended on to do their part in protecting and maintaining vital rail lines!



Users are urged to check their motors at regular intervals to insure top performance and longer life. In case replacement parts or service are needed, get them from your regular dealer or from an Authorized Briggs & Stratton Service Station.

Briggs & Stratton motors are now being "drafted" for the duration — and are available only to those whose equipment is serving the war program. If your products fall in these classes we will try to help you.

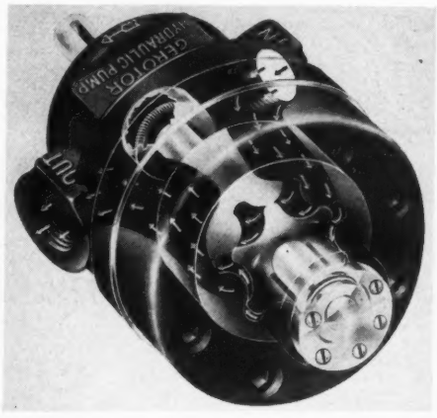
BRIGGS & STRATTON CORP., *Milwaukee, Wis., U. S. A.*

4 CYCLE BRIGGS & STRATTON GASOLINE MOTORS

this service helps aircraft companies to eliminate the time of machine countersinking in their own plants. The present line of plain rivet holes is augmented by the addition of dimpled rivet holes for use with 78-degree and 100-degree countersunk rivets. Parts with rivet holes so specified are identified by adding suffixes to the standard part number.

Pumps and Hydraulic Motors

MANUFACTURED by Gerotor May division, May Oil Burner Corp., Baltimore, are pumps and hydraulic motors, for industrial and military applications where in addition to high efficiency, requirements call for durability, simplicity and minimum of occupied space. Gerotor pump delivers from .4 to 50 gallons per minute while the hydraulic motors are designed to meet the particular application. The units are of the positive displacement type with a unique internal rotor movement in which the inner Gerotor has only one less tooth than the outer Gerotor. Each tooth of the inner one is in sliding contact with the tooth contour of the outer at all times as both Gerotors revolve in the same direction with low relative speed, providing continuous, fluid-tight engagement. This makes for high volumetric efficiency and results in low friction losses, plus providing high mechanical efficiency and long life.



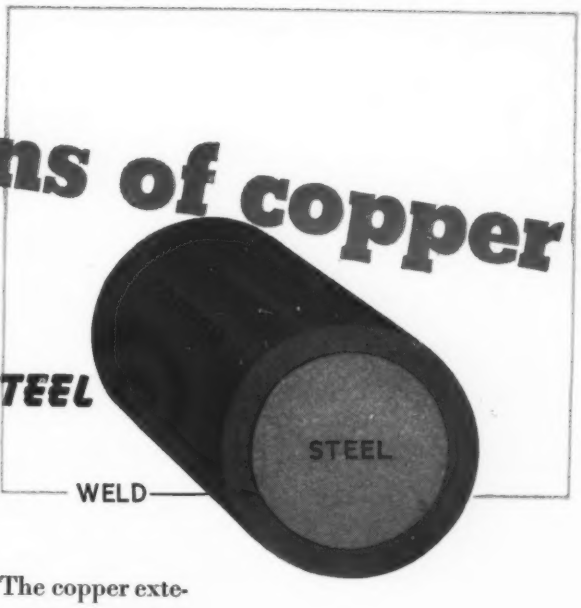
Develops Olive Drab Coatings

FOR protecting machinery and exposed steel work, Carbozite, a standard coating, is now available in two types through Carbozite Corp., 906 First National Bank building, Pittsburgh, in government-approved olive drab in addition to the usual black, red, green and gray colors. The finish can be applied by brushing, spraying, or dipping and resists corrosion of acids, alkalies, moisture, sulphur water, salt air and smoke. Shop coating for prime coats or protection is quick-drying and can be sprayed, brushed or dipped. It is of particular use as primer or protection of products being shipped in open cars or overseas. The textile coating is intended for use in waterproofing and pre-

Hundreds of tons of copper can be saved—

—BY USING **COPPER-COVERED STEEL**
(COPPERWELD)

IN PLACE OF COPPER, BRONZE OR BRASS



"Copperweld" is steel wire or rod, copper covered. The copper exterior is permanently welded (cast) to the steel core. "Copperweld" resists rust and corrosion like copper, provides adequate electrical conductivity for many electrical uses and rust-resisting high strength for many mechanical uses.

"Copperweld" can be used wherever rust-resisting strength or electrical conductivity is needed. "Copperweld" will do many jobs for which copper, bronze or brass have been used—and will do them with *much less copper*.

COPPERWELD STEEL COMPANY, GLASSPORT, PA.

COPPERWELD COPPER-COVERED STEEL

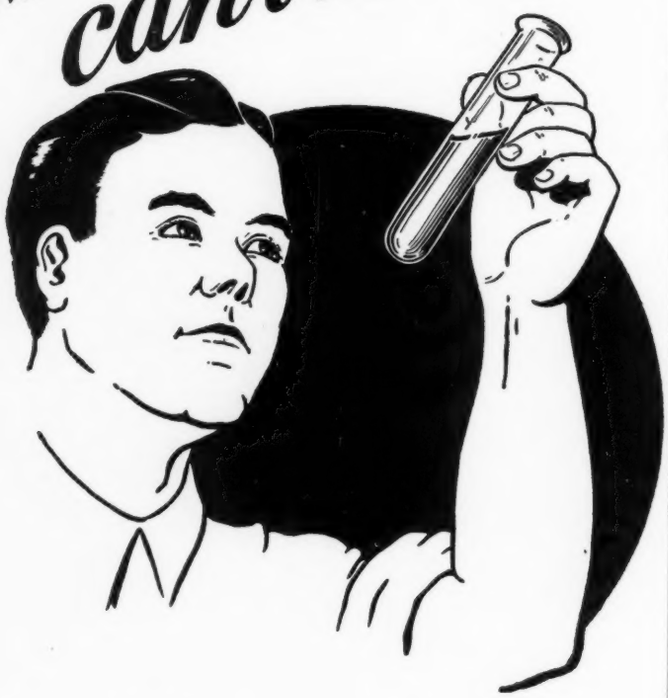
EXAMINE THIS MATERIAL FOR YOURSELF—*Phone or write our nearest office*

DISTRICT OFFICES

ATLANTA	*1105 Rhodes-Haverty Building*
CHICAGO	*122 S. Michigan Ave.*
CLEVELAND	*415 Swetland Building*
DALLAS	*4321 Glenwick Lane*
NEW YORK	*117 Liberty Street*
SAN FRANCISCO	*526 Rialto Building, 116 New Montgomery St.*
WASHINGTON, D. C.	*815 15th Street, N. W.*

"Copperweld" has been used for 27 years by the nation's leading Power Companies, Railroads and Telephone Companies.

MAYBE IT *can't* BE DONE



That doesn't mean our research chemists are going to stop trying to improve it.

When and if better tracing cloth than Micro-Weave can be produced, Holliston Mills aim to be first to make it.

Meanwhile, why not let Micro-Weave prove itself on your own drafting board?

Send for generous size sample or ask your dealer.

THE HOLLISTON MILLS, Inc.
NORWOOD, MASS.

BOSTON NEW YORK PHILADELPHIA
CHICAGO ST. LOUIS RICHMOND

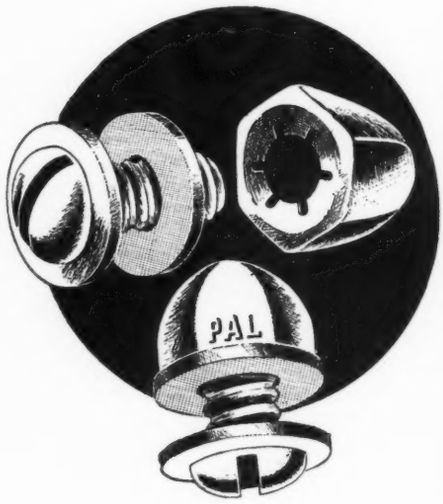
Micro-Weave
All American
TRACING CLOTH

Micro-Weave
MORE THAN 180 FLAWLESS THREADS PER SQ. INCH

serving fabric. Addition of olive drab color in this line extends its use for military purposes.

Self-Locking Nuts Announced

AVAILABLE in three popular bolt sizes—6-32, 10-24 and ¼-20 new acorn type nuts have been introduced by The Palnut Co., 61 Cordier street, Irvington, N. J. Similar in design to the company's regular Palnuts, they have the same spring steel jaws that close in and grip the bolt



thread when the nut is tightened. The six upright sides have been extended up and crowned over, coming together at the top to form an acorn or cap nut design. Light in weight but relatively strong, they can be used on many assemblies to replace regular acorn nuts or nuts with lockwashers, and are also used to lock regular nuts tight on heavier types of assembly.

Colloidal Graphite Lubricant

TO REDUCE bearing wear, prevent overheating, reduce friction, act as corrosion inhibitor, be unaffected by acid and to stand temperatures up to 5000 to 6000 are said to be characteristics of Konag F, a colloidal graphite for general lubricating purposes offered by National Graphite Co. Inc., 17 John street, New York. This material is suggested for lubricating of bearings, motors, generators, drill presses, compressors, conveyors, precision tools, hoists, gears and diesel engines. It may be mixed with general lubricant at ratio of 10 per cent solution.

Self-Operating Controllers

ENTIRELY self-contained and self-operating, new temperature controllers brought out by The C. J. Tagliabue Mfg. Co., Park and Nostrand avenues, Brooklyn, N. Y., accurately regulate temperature of steamheated equipment such as hot

Announcing

A MANAGEMENT POLICY

THE new management of the ROMEC PUMP COMPANY makes a pledge. That pledge is to produce and deliver aircraft pumps which in quality and performance will continue to be classed farther "out in front."

ROMEC engineers pioneered the non-pulsating fuel pump years ago, and ROMEC pumps were among the first to pump the fuel for the earliest globe-circling flights. Today they are pumping in planes over 5 oceans and both hemispheres.

We shall not only continue to build pumps that improve with use but we shall constantly strive to build even *better* pumps, if that is possible. As the pilot cannot perform better than his heart, so the planes and motors cannot perform better than their pumps.

We repeat the pledge to keep ROMEC pump DEPENDABILITY "out in front."

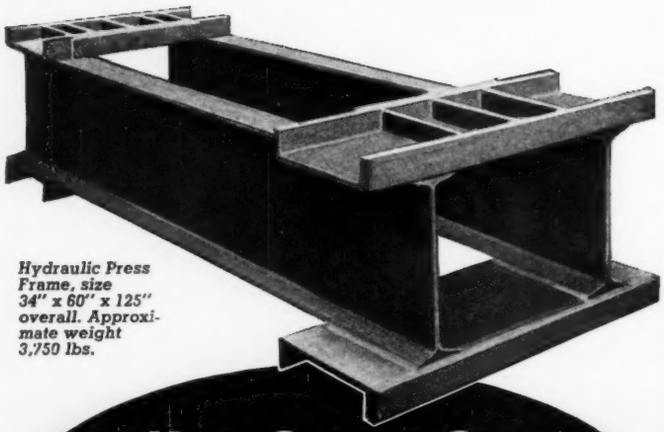
THE ROMEC PUMP COMPANY

Ralph H. McOuat
President

ROMEC

PUMP COMPANY

ELYRIA · OHIO · U. S. A.



Hydraulic Press Frame, size 34" x 60" x 125" overall. Approximate weight 3,750 lbs.

How Graver Can CUT COSTS and SPEED PRODUCTION for you—

Machinery bases and frames can be welded by Graver in less time than would be required to make patterns for castings. Here's a definite saving of time — and no pattern expense.

A Graver-welded job is delivered to you ready for use — only a minimum of machining necessary. Again — time and money saved.

When a combination of two or more dissimilar metals — mild steels, alloy steels, steel castings or forgings — is required, they can be quickly welded into a single unit, thus increasing the life of the unit and eliminating repairs and replacement parts. That's a further saving in time and money.

There is no dead weight in Graver-welded machine bases. Ample strength and weight where needed, but no excess metal.

Modern equipment plus expertly trained and experienced welders insure a finished product that will meet the most rigid requirements both in specifications and inspection, and the phrase "Welded by Graver" has come to mean complete satisfaction — economy — and production speed — to Graver customers.

Write for our latest bulletin showing typical Graver-welded jobs.

GRAVER

STEEL STORAGE TANKS · VAPOR CONSERVATION SYSTEMS
WELDED CONSTRUCTION · STRESS RELIEVING · X-RAYING
FABRICATED STEEL AND NON-CORROSIVE PLATE · WATER SOFTENERS
FILTRATION SYSTEMS · CLARIFIERS · SEWAGE EQUIPMENT

GRAVER TANK & MFG. CO., INC.

4809-36 TOD AVE.
EAST CHICAGO, IND.
CABLE ADDRESS — GRATANK

NEW YORK · CATASAUQUA, PA. · CHICAGO · TULSA

42-17-S

water storage heaters, canning retorts, exhaust boxes, textile dryers and scouring bowls. No external source of power is necessary, energy being developed in its own system. Temperature changes at sensitive element or bulb in apparatus under

regulation, raises or lowers the vapor pressure of the volatile liquid in the tube system. Capillary connecting tube transmits pressure change to the power bellows. Bellows expand and contract in response to the temperature changes at bulb, position the steam valve and so control the temperature.

Molded Compound Tires

INDUSTRIAL wheels of cast semisteel can now be obtained from French & Hecht Inc., 777 Farman street, Davenport, Ia., with molded-on compound tires, said to replace rubber satisfactorily for this use. Depending upon the service required of wheels, three types of compound can be supplied. The standard type is used for all normal duties; oil-resistant type for service where oils and grease are prevalent; and static dissipating compound for use in ordnance plants, chemical plants, flour mills, grain elevators and other places where static discharge is a hazard. Diameters of wheels range from 4½ to 20 inches. Wheels are suitable for use on hand trucks and other material handling equipment, as well as on portable tools.

Small Lightweight Motor

WEIGHING only 1½ pounds and measuring less than 3 inches overall, the new direct-current motor designed especially for aircraft use by Electric Motor Corp., Racine, Wis., gives power and speed without bulk and weight. The unit can be wound to develop 1/13 horsepower at 8500 revolutions per minute. Other ratings are available in the same frame, and the motor can be wound

INSTALL ONE unit . . . DO 4 jobs

WITH WESTINGHOUSE COMBINATION LINESTARTERS for a-c motor circuits

Size 1 Combination Linestarter, Class 11-206

Westinghouse Nofuze Circuit Breaker

1 ACTS AS MANUAL DISCONNECT SWITCH. Locking arrangement permits padlocking cabinet closed and switch in off position. Eliminates need for separate switch. "De-ion" arc quenching protects contacts.

2 PROTECTS CIRCUIT AGAINST OVERLOADS. Bi-Metal gives positive protection against short circuits and severe overloads . . . does away with need for fuse equipment. Unvarying — factory-calibrated — self-indicating.

Westinghouse "De-ion" Linestarter

3 GIVES MAGNETIC ACROSS-THE-LINE STARTING. Permits operating motors by push button, float or pressure switch. Contacts opened and closed by direct-acting, vertical solenoid magnet. "De-ion" arc quenchers protect contacts.

4 PROTECTS MOTOR AGAINST OVERLOADS. Bi-Metal relay calibrated to protect motor permits momentary overloads as in starting, but protects motors from sustained overloads.

Save wiring—save time—save space! This single "package" contains everything you need for the motor circuit in one compact, easily installed enclosure.

Westinghouse Combination Linestarters combine the advantages of Nofuze Circuit Breakers and "De-ion" Linestarters. They eliminate delays for fuse replacements, and simplify the job of providing proper control and protection for motor circuits. Specify them . . . install ONE unit—and do FOUR jobs! Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. J-21186-A

Westinghouse

Ampco Metal has answered many a production and operating problem of wear, shock, and corrosion. Every day new problems arise in your plant that demand your answer. Knowledge of Ampco Metal is the best insurance you can have that your answer will effect the desired result without costly experimentation.

Authentic case histories, pertinent engineering data, impartial discussions of the selection of bronzes for varied applications and detailed physical properties are presented in the Ampco Metal Engineering Data Sheets. These are mailed monthly to engineers and key executives interested in knowing the answers in Ampco Metal.

Behind the preparation of these Data Sheets lie 28 years of experience in serving over 2000 outstanding companies in American industry—experience that may be yours for the asking. May we place your name on our mailing list?

AMPCO METAL, INC.

Dept. MD-8 **Milwaukee, Wis.**

AMPCO METAL

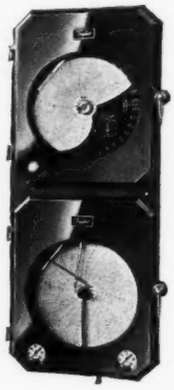
AMPCO

THE METAL WITHOUT AN EQUAL

for operation on any voltage. It is designed to conform to Army Air Corps specifications.

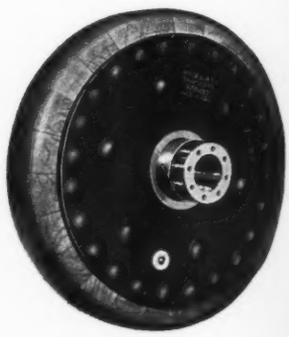
Time Schedule Controller

WITH the new Fulscope time schedule controller, developed by Taylor Instrument Companies, Rochester, N. Y., processing schedules can be maintained under precise conditions of temperature, pressure, flow or liquid level. It is possible with this instrument to repeat the process automatically as many times as desired. Cam and chart are individually mounted and conveniently located for instant visual comparison. Some of the improved features of the controller are: Friction drive assembly, permitting rotation of cam without loosening of locking devices; each cam being capable of operating from one to four air valves, switches or both for actuation of any external mechanism such as bell or light, and of doing this automatically in any desired relation of one to the other; and automatic return of cam to starting position. An optional feature of the controller is the interrupter timer which allows extreme flexibility to both the rise and the holding periods of the process under control. This timing feature allows the use of a very fast cam clock for a rapid rising period, but reduces speed of clock to increase length of holding period. Entire unit is housed in universal case for either face or flush mounting.



Wooden Truck Wheels

IN REGULAR-DUTY, heavy-duty and super-strength types, a new End-Wood wheel is being marketed by The Metzgar Co., Grand Rapids, Mich. Available in sizes from 2½ up to 20 inches in diameter, the wheels are of hard maple, assembled and bound tightly by rivets through steel disks on sides. They are fitted either with or prepared for cage-type Hyatt or similar roller bearing types. Any thickness of face may be had, and guarantee is given against breaking. The wheels run quietly and are not destructive to floors and roadways. Obtainable under an A-1-J or higher priority rating, the wheels fit all different types of hand trucks, two-wheel trucks, dollies, platform trucks and trailers.



Four Delco fractional motors power this special machine which performs precision-drilling operation on cylinder liners. *Dynamically-balanced* Delco motors contribute to machining accuracy.

The Hum of Machines—Symphony of Victory

In factories great and small, the chips are flying as machine tools fill the air with a Symphony of Victory. Some of these machines are shining new masterpieces of engineering, built to do their job better and faster than it was ever done before; others are scarred and battered old veterans that have been converted to war assignments by sweat and ingenuity. Together they are giving America's answer to the Axis' challenge: guns, planes, tanks, ships, shells and supplies to win the war.

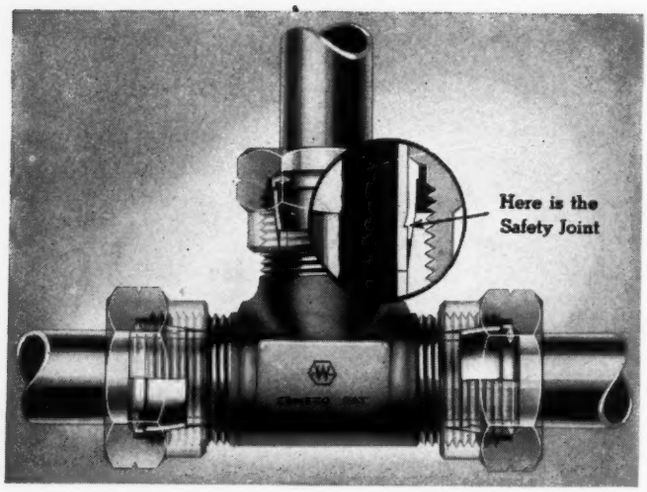
Delco motors drive machine tools of all types and conditions in this battle of production. Their dependable performance—product of experienced designing, precision manufacturing and rugged construction—helps machines hit top capacity day after day. Delco motors run cool when "the heat's on" . . . run smooth when the going is tough . . . and keep running.

Delco motors will provide satisfactory performance on your machine tools.

DELCO MOTORS

DIVISION OF GENERAL MOTORS CORPORATION

DELCO PRODUCTS · DAYTON, OHIO



★ ERMETO ★

FITTINGS

Quickly connected... quickly disconnected

★ NO FLARING, THREADING SOLDERING OR WELDING ★

THE unique principle on which Ermeto Safety Tube and Pipe couplings are designed makes them the easiest fittings to connect or disconnect without the necessity of flaring, threading, welding or soldering.

With Ermeto Safety Fittings, connections can be made with practically all types of metallic tubing materials. *And the joints will hold up beyond the burst strength of the tubing itself.* Exhaustive tests have also proved the superior qualities of Ermeto in the ability to withstand vibration without loss of tightness in the joint.

If your equipment carries hydraulic or oiling systems, or you use gas, water, fuel and air lines, write for complete information on Ermeto—the safety fitting.

THE WEATHERHEAD COMPANY 300 East 131st St. CLEVELAND, OHIO

WEATHERHEAD

TUBE FITTINGS • FLEXIBLE HOSE • VALVES • DRAIN COCKS
AVIATION, AUTOMOTIVE AND REFRIGERATION SPECIALTIES

MEN *Of Machines*

FOR ten years engineer - in - charge of Allis - Chalmers Mfg. Co. A-C design, S. H. Mortensen has been appointed chief electrical engineer of the company's plant at West Allis, Cincinnati, Boston and Pittsburgh. Mr. Mortensen started with the company's Norwood works in 1905 and was transferred to Milwaukee as an electrical draftsman three years later. Successively he became design engineer for D-C machines, design engineer of rotating synchronous machines, and in 1932 engineer-in-charge of alternating current design. Born in Denmark, Mr. Mortensen studied in Europe before coming to America. He has been responsible for pioneer work in the development of self-starting synchronous motors, synchronous condensers and turbo-generators. Mr. Mortensen also has contributed numerous articles and papers on electrical operation and design to the leading professional papers, and has written a textbook on Motor and Generator Design. More recently he was a co-author of the Standard Handbook for Electrical Engineers.

♦

CHARLES A. MABEY has been appointed director of research activities at the Bristol Co., Waterbury, Conn. He has been associated with companies such as International Communications Laboratories of New York, and Federal Telegraph Co.

♦

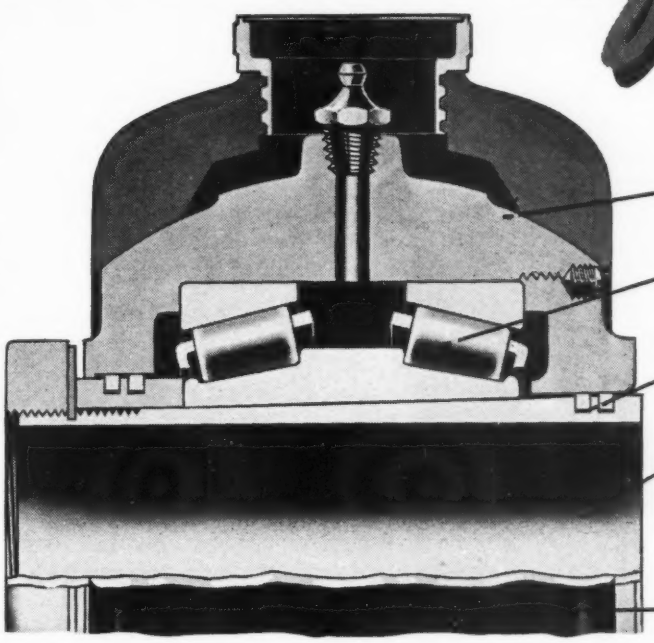
RACY D. BENNETT has joined the engineering staff of the Vinco Corp., Detroit, as development engineer. He formerly operated for two years an engineering and consulting service, and for five years was with the Ex-Cell-O Corp.

♦

G. J. COMSTOCK, professor of powder metallurgy at Stevens Institute of Technology, has been ap-

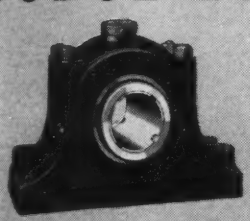
They Can Take a Beating *for Victory!*

HIGH SPEEDS
HEAVY DUTY
SHOCK LOADS

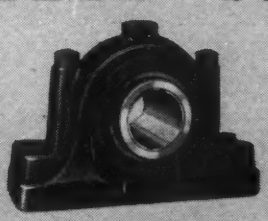


1. ● Full ball and socket self alignment.
2. ● Timken tapered roller bearings give full radial and thrust capacity.
3. ● All metal automotive type piston ring seals keep grease in and dirt out.
4. ● Long split adapter sleeve distributes load over entire length of bearing — reduces pressure per square inch on shaft and eliminates peening action which causes rapid wear.
5. ● Rugged, well proportioned outer housing.

DODGE-TIMKEN SPECIAL DUTY BEARINGS

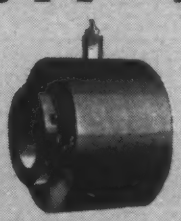


Dodge-Timken Special Duty Ball and Socket Pillow Blocks

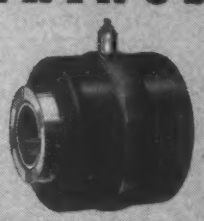


Dodge-Timken Special Duty "S 1" Pillow Blocks

Dodge-Timken Special Duty "D" Unit Mount



Dodge-Timken Special Duty "B 1" Unit Mount



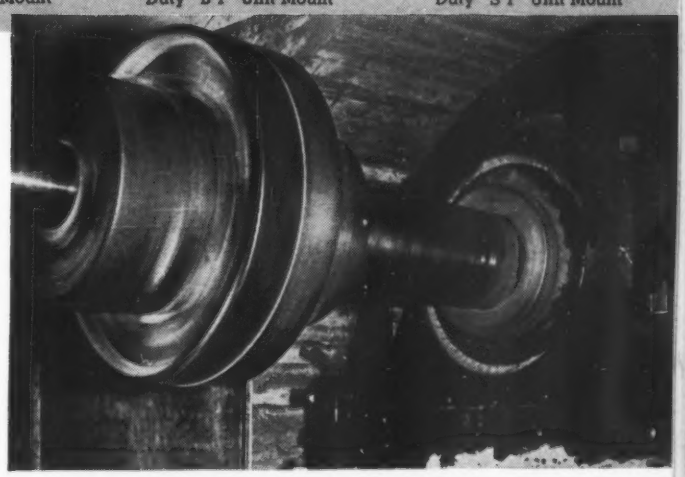
Dodge-Timken Special Duty "S 1" Unit Mount

DODGE-TIMKEN bearings can take the beatings handed out by today's 24-hour production on week-in and week-out schedules. They are designed to give a minimum of 30,000 hours of service under conditions for which they are adapted.

Available in a wide variety of sizes and types — Dodge bearings offer lubricating features that guard against possible neglect by "green" shop help. Indestructible steel seals prevent lubrication leakage — require only infrequent attention from oilers — protect production schedules.

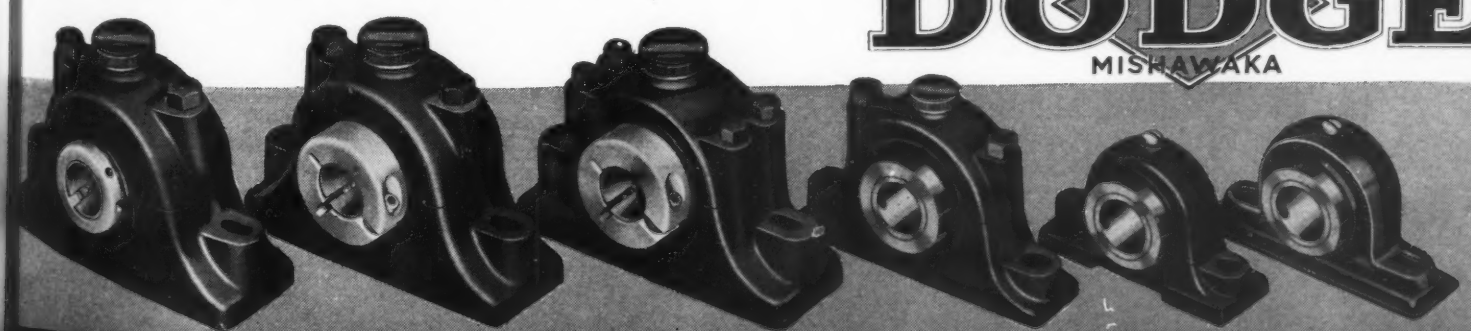
Put all your power into production with Dodge anti-friction bearings — insure unbroken operation with Dodge ruggedness and stamina. Dodge distributors, located in important industrial centers from coast to coast, are prepared to check over your power transmission equipment — help you in the application of the right bearing for the job. Call the one nearest you or write us direct today for Bulletin A 206 and Selection Tables.

DODGE MANUFACTURING CORPORATION
MISHAWAKA, INDIANA, U.S.A.



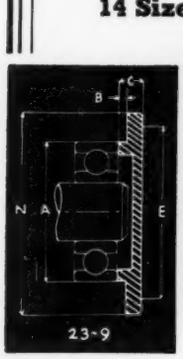
Dodge-Timken Special Duty Pillow Blocks help modernize power transmission and solve increased production problems in an important North Carolina textile mill.

DODGE
MISHAWAKA

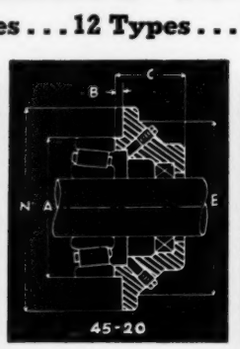


DODGE ROLLING BEARINGS . . . The 30,000 Hour Line

R-S Standard
BEARING COVERS
14 Sizes . . . 12 Types . . . 3 Depths



23-9



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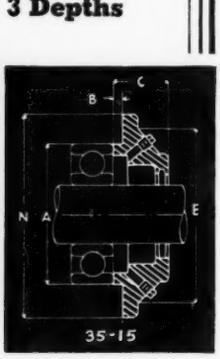


35-15

Description	"A" Bearing O.D.	"B" Depth Rabbit	"C"	"E" Bolt Center	"N"	No. and Size Bolts	Shaft	O.D. Oil Seal
#23-9	2.2500	1/8"	7/64"	3"	—	4—3/8"	—	—
#45-20	5.000	3/16"	2 1/4"	6"	7"	6—1/2"	2 1/8"	3.555" —FELT— 3/16"x3/16"
#35-15	3.5433	1/8"	1 7/64"	4 1/2"	5 1/4"	4—3/8"	1 11/16"	

Reduce "Nuisance" Set-Ups

Why tie up costly equipment in order to make bearing covers?

R-S *Standard* Bearing Covers can be obtained in fourteen sizes of flat, medium or deep construction (closed, open with felt, oil seal or flinger types). Fit all standard size ball and roller bearings and approved by all leading bearing manufacturers.

Where these covers are used to clamp bearings and, therefore, act as thrust resisting members in many cases, the bolts fastening the cover to the housing are located at the proper distance from the center in order to prevent deflection under thrust.

High-grade cast iron castings with the mating surfaces and diameters machined accurately to accepted tolerances. Low unit cost whether you require ten or ten thousand.

Order by number from stock. Write for Bulletin No. 11-C. It contains full particulars, dimensions and detailed drawings.

Bearing Appliance Division

R-S PRODUCTS CORPORATION

112 Berkley Street · Philadelphia, Pa.

pointed technical consultant of the U. S. Board of Economic Warfare in the Industrial Engineering division.

♦

GEORGE W. WALKER has been appointed a consultant to BRIG. GEN. G. M. BARNES, chief of the research and development service. Mr. Walker, an industrial designer, will devote time to studies of streamlining the Army's automotive vehicles.

♦

JOHN S. DUDLEY of Chrysler Corp. is in charge of the development of a laboratory and training course on rubber and plastics, sponsored by the Detroit Rubber and Plastics Group of which J. H. DOERING of Ford Motor Co. is chairman.

♦

DR. W. W. DESCHNER, previously in charge of the department of chemical engineering at the University of Kansas, has been named head of the new division of chemical design, engineering and construction of J. F. Pritchard & Co., Kansas City.

♦

HAROLD V. COES, vice president of Ford, Bacon & Davis Inc., New York, has been nominated as president for 1943 of the American Society of Mechanical Engineers.

♦

EDSEL B. FORD, president of Ford Motor Co., has been made president of the Horace H. Rackham Engineering Foundation, Detroit.

♦

ORMOND E. HUNT was recently awarded the honorary degree of doctor of science in engineering at the annual commencement exercises of Wayne University. Mr. Hunt is vice president and director of engineering of General Motors Corp.

♦

ROGER MATHER has been appointed to the engineering staff of Willys-Overland Motors. He formerly was connected with Inland Steel Co.

ELECTED president of the American Institute of Electrical Engineers, Harold S. Osborne has had considerable experience in electrical engineering to enable him adequately to fulfill his new duties as president of the institute. His present connection is that of plant engineer, operation and engineering department, American Telephone and Telegraph Co., New York. Born in Fayetteville, N. Y., in 1887, Mr. Osborne was graduated from Massachusetts Institute of Technology

Here are ALL the Facts

You Need to Know About Precision Snap-Action Switches

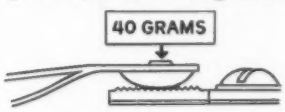
Thumb Size
The Micro Switch is 1 15/16" long, 27/32" high, 11/16" wide

Feather Light

The Micro Switch gives you longer switch life than you will ever need —*millions of operations*

The Micro Switch assures you precise and accurate repeat operation

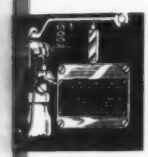
The Micro Switch gives you a normally closed contact pressure of 40 grams



Lightning-fast contact action—
Contacts move from one position to the other in 3/1000 to 5/1000 of a second

...ns of better performance are meaningless unless they are verified by actual data regarding what ...lly happens. The Micro Switch is accurately built to exact standards from precisely made parts. ...ls regarding this precision and accuracy are set forth on this page. Study the operating principle ...e Micro Switch and you will understand why it will give you longer life than you will ever need...why ...ll operate precisely at the same point time after time ...how it gives you greater contact pressure and ...r contact action. The Micro Switch is listed by Underwriters' Laboratories with ratings of 1200 V.A. ..., from 125 to 600 Volts A.C.

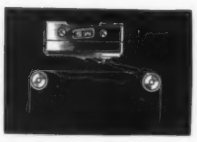
How and For What ...cro Switches Are Used



This shows an explosion proof Micro Switch used with a spray gun which automatically cuts out the entire operation of the spraying booth when the gun is shut off.

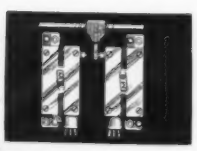
...illustration shows ...cro Switch with a ...button actuator ... used as a safety ... in a high tension ...r door. It is a nor... open switch in ... the circuit is opened as the door is opened

This illustration shows the use of two Micro Switches with spring type plungers to insure safe positioning of material in a punch press or a similar tool.



...illustration shows ...icro Switch with a ...g leaf actuator serv... a break indicator ...d in textile mills or ... mills.

This illustration shows a Micro Switch enclosed in a die cast housing with a synthetic rubber seal, and is being used as a lathe carriage stop.



...illustration shows ...eel enclosed Micro ...es which serve as ...n limit switches on ...chine tool.

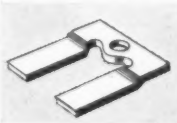
This illustration shows use of a Micro Switch with a spring plunger which is actuated by the pressure of a liquid in a line as the actuating medium.

Here's the Operating Principle

The operating principle, as illustrated here, is simple and fundamentally correct. The long member of the one piece spring "B" is supported in a cantilever at "A". The two short members of the spring and the exact shape of the V's (patented) produces a bearing of such low friction that when the plunger at "D" deforms the long tension member, the cantilever force overcomes the vertical force supplied by the two compression members and the free or contact end of the spring "E" snaps from one stop to the other with lightning-fast speed. Reverse action occurs when the deformation of the tension members of the spring by plunger "D" is removed. The cantilever force then becomes less than the vertical force supplied by the compression members.

The Micro Switch spring is made in one piece of beryllium-copper. It is held to an accurately gauged thickness of .0085" and is heat treated to provide high resistance to fatigue. Every lot is under laboratory control to insure maximum flexure life—5,000,000 operations to full overtravel for the minimum. The ends of the two compression members of the spring are especially finished to provide an extremely low friction bearing.

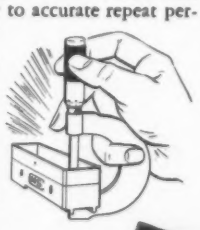
The short compression members of the spring pivot in the patented V-grooves of the sturdy brass anchor illustrated here. Note the special shape of these grooves. This shape, plus the specially finished edge of the compression members of the spring, reduce friction to a minimum.



The contact end of the spring is fitted with a riveted radius type contact of 99.95% fine silver. As the plunger is actuated, this contact moves from one position to the other in 3/1000 to 5/1000 of a second with a rolling action which minimizes the effects of welding. The stationary contact is a flat inlay of 99.95% fine silver. Its large area provides maximum heat dissipation.

The operating plunger consists of a highly polished, stainless steel pin set into an accurately moulded star-shaped Bakelite head. Its size and form provide a long over-surface path to live parts, thus insuring freedom from electrical leakage. The star-shaped plunger head cannot rotate within the housing, insuring against any large variation in point of operation. The Bakelite head comes to rest against the anchor within .020" after actuation occurs, thus preventing excessive overtravel, and insuring maximum spring life.

The housing of the Micro Switch is Bakelite, moulded to high precision. The deep, box-like construction insures the rigidity necessary to accurate repeat performance for millions of operations over wide ranges of temperature. The electrical resistance of this housing (between the nearest live parts) has a minimum value of 10,000 megohms. The covers are made of vividly colored Plaskon and must meet the same precision requirements.



SEND FOR THESE CATALOGS

Your up-to-the-minute engineers will thank you for keeping them informed about the Micro Switch. Send for as many of the Handbook-Catalogs illustrated here as you think necessary. No. 60 covers Micro Switches in general; and No. 70 deals with specific Micro Switches for use in aircraft.

Micro Switch is a trade name indicating manufacture by Micro Switch Corporation

MICRO MS SWITCH

Manufactured in FREEPORT, Illinois by Micro Switch Corporation

© 1942

Branches: 43 East Ohio St., Chicago · 11 Park Place, New York City · Sales and Engineering Offices: Boston, Hartford, Los Angeles

"EXTRUDED TUBING" "METALLIC BELLOWS"

For aircraft radiators, oil coolers, inter-coolers, and heat interchangers; for liquid-cooled and air-cooled motors.

For all types of temperature and pressure control devices for aircraft engine cooling systems, carburetors and super-chargers.

CLIFFORD MANUFACTURING CO.
564 E. FIRST STREET, BOSTON
BOSTON · CHICAGO · DETROIT

LEE-BUILT SPRINGS
— always dependable

THE supplier needs a thousand eyes to foresee all customer demands— the buyer needs but one, to spot a supplier having those thousand eyes.

Ask About SCIENTECH Spring Service

LEE-BUILT TRADE MARK SPRINGS

LEE SPRING CO., Inc.
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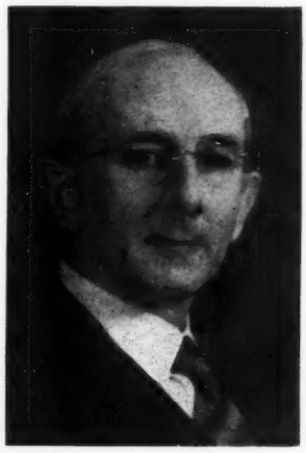
in 1908 with a bachelor of science degree. In 1910 he joined the American Telephone & Telegraph Co. as an engineer in the transmission and protection department, and in four years became assistant to the transmission and protection engineer. Rising to transmission engineer in 1920 he remained in this position until 1939 when he was made operating results engineer. A year later he was appointed plant engineer, the position he holds to date. Mr. Osborne has about 35 inventions in the field of telephony and telegraphy. He is the author of several books and contributions to technical journals.

♦

WILLIAM IEKEL, special equipment designer, Kearney & Trecker Corp., has been elected chairman of the Milwaukee chapter, American Society of Tool Engineers. PAUL O. WERNICKE, chief engineer, Stokerunit Corp., is secretary, and ROLAND N. NAVERTZ, tool engineer of Cutler-Hammer Inc., is treasurer.



NOMINATION of H. J. Ball as president of the American Society for Testing Materials has been announced. Professor of textile engineering at Lowell Textile institute, he has been active for a long time in the society. Since 1930 he has been a member and chairman of the society's largest and most active committee, Committee D-13 on Textile Materials, and has contributed notably to the advancement of standardization and research work in this field. From 1934 to 1936 and again from 1939 to 1940 he was a member of the society's executive committee. For two years from 1940 to 1942 he served as vice president of the society and also rendered service as a member of the Committee E-6 on Papers and Publications. He is also a member of The American Society of Mechanical Engineers, Textile Research Institute Inc., and the British Textile Institute Inc.

Professor Ball received his B.S. degree in mechanical engineering in 1906 from the Massachusetts Institute of Technology. Joining the faculty at Lowell, he was made head of the Textile Engineering department in 1918. He holds the degree of B.C.S. (with honor) from Northeastern.

♦

S. E. LAUER has been elected a director of the American Management association, New York, to serve a three-year term. He is president of York Ice Machinery Corp., York, Pa.

28 Tons Sitting on Nothing

TO PULL THIS 28-TON LEVIATHAN into the air—to keep it flying—requires engines of super horsepower—engines that didn't exist, except on a drawing board, not so many months ago.

How the power of 1500 horses can be compressed into an engine hardly wider than your outstretched arm—how this terrific force can be delivered to turn a propeller at the end of a shaft is all a part of America's industrial genius.

A secret of the modern airplane engine's might is gears—gears so light in weight, ground to such close tolerances that engineers almost despaired of ever producing them except under laboratory conditions.

But the urgency of war demanded that these gears be mass produced at no sacrifice in lightness or precision. Today in the plant of Foote Bros. Gear and Machine Corporation these "jewels of power transmission" are flowing out to help power American planes.

All this meant new manufacturing techniques—new production methods. American manufacturers may look forward with confidence to the application of these developments to peacetime speed reducers and gears to assure better machines—quieter machines—produced at lower cost.

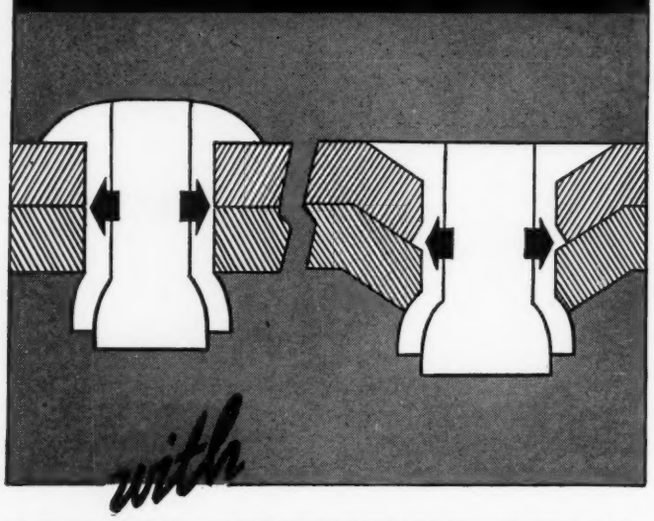
FOOTE BROS. GEAR AND MACHINE CORPORATION
5301 S. Western Boulevard • Chicago, Illinois

D. Torque

FOOTE BROS.

SPEED REDUCERS ★ GEARS ★ SPECIAL ASSEMBLIES

A Blind RIVET



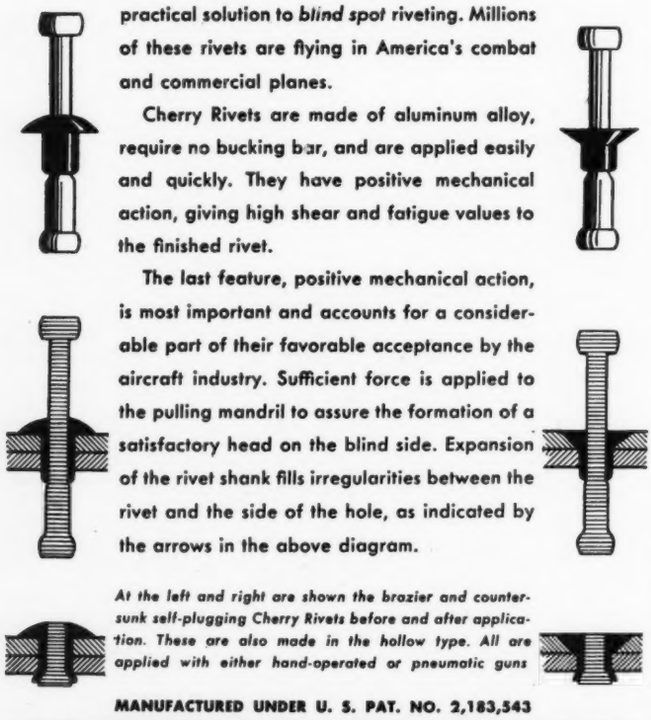
with

POSITIVE MECHANICAL ACTION

A great many aircraft manufacturers have found that Cherry Blind Rivets offer a highly practical solution to *blind spot* riveting. Millions of these rivets are flying in America's combat and commercial planes.

Cherry Rivets are made of aluminum alloy, require no bucking bar, and are applied easily and quickly. They have positive mechanical action, giving high shear and fatigue values to the finished rivet.

The last feature, positive mechanical action, is most important and accounts for a considerable part of their favorable acceptance by the aircraft industry. Sufficient force is applied to the pulling mandril to assure the formation of a satisfactory head on the blind side. Expansion of the rivet shank fills irregularities between the rivet and the side of the hole, as indicated by the arrows in the above diagram.



At the left and right are shown the brazier and countersunk self-plugging Cherry Rivets before and after application. These are also made in the hollow type. All are applied with either hand-operated or pneumatic guns

MANUFACTURED UNDER U. S. PAT. NO. 2,183,543

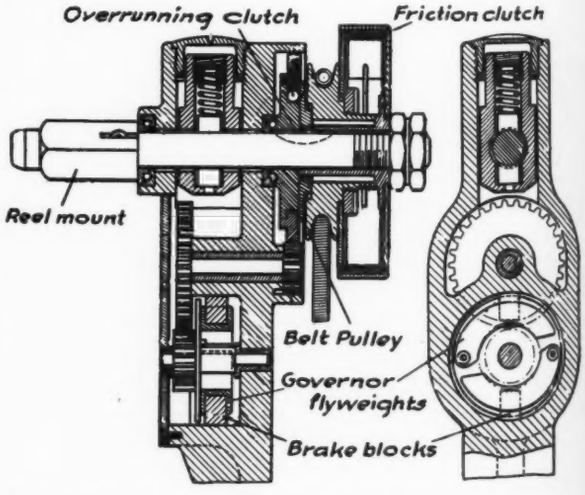
Cherry Rivet
Company
LOS ANGELES, CALIFORNIA
© 1942 C.R.C.

Noteworthy PATENTS

Reel Winder Is Tension Controlled

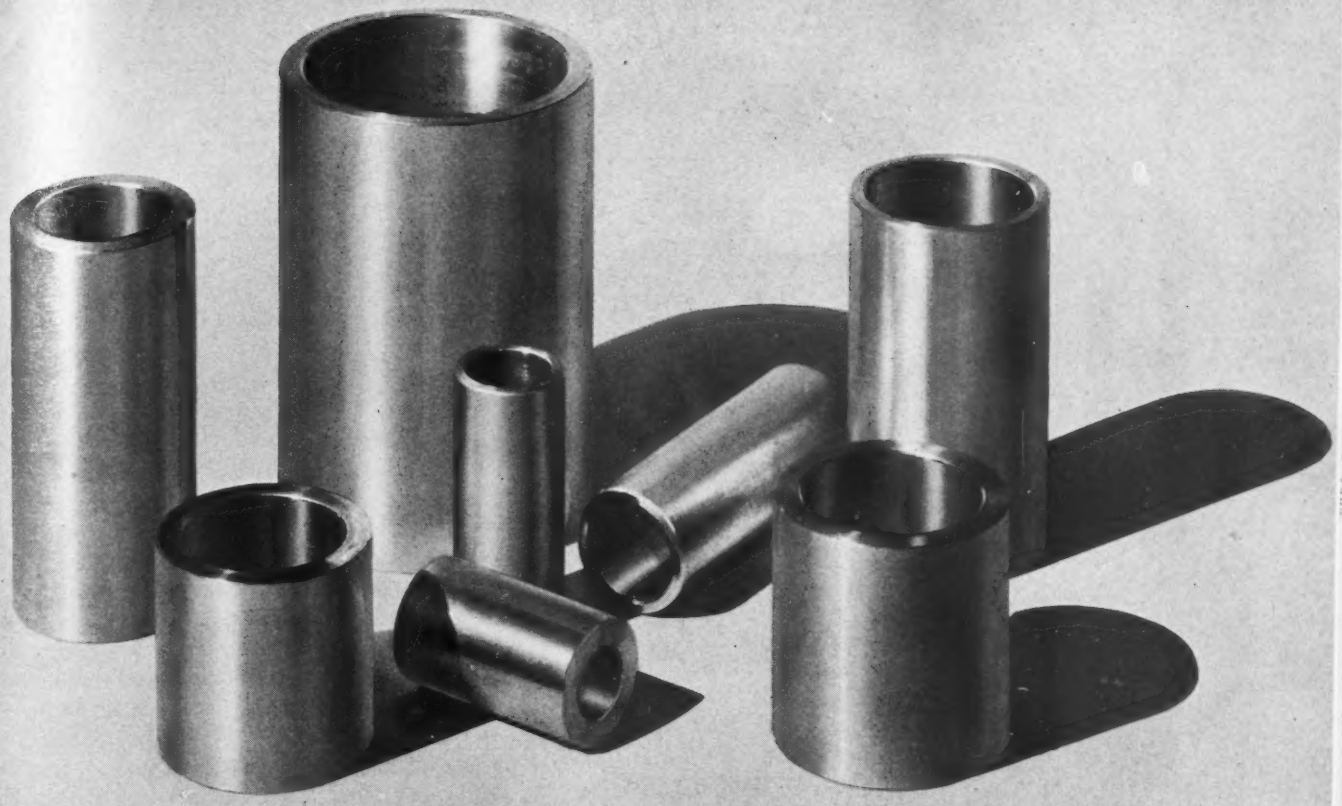
WINDING mechanisms such as are used for reeling film in motion-picture machines must rotate at varying speed as the film roll diameter changes, since the linear speed of the film is constant. With earlier take-up reel-driving mechanisms the torque was constant, which meant that the tension in the film changed with the diameter. Compensation for this undesirable effect is provided in a recent patent assigned to the Bell and Howell Co.

Reel mount is driven through a spring-controlled friction clutch which transmits substantially constant torque when slipping and allows the reel to be driven at variable speed. Torque is sufficient to give adequate film tension when the film roll diameter is maximum. Excessive tension when



Brake actuated by governor flyweights absorbs excess power at high speed

the roll diameter is small is prevented by a speed-controlled brake which absorbs the surplus power. Driven through increasing gears, the brake consists of a pair of pivoted governor flyweights actuating brake blocks, pressing them against the housing with a force which increases with the speed. Maximum power is therefore absorbed at the brake when the speed is highest and the film



Specifying *OD, ID and Length is not enough*
...you need proven serviceability too

• 1088 stock sizes of Buckeye fully finished ready-to-use phospher bronze bearings, one or another of which is the proven time-tested answer to most bearing requirements — 560 sizes of Buckeye cored and solid, rough and finished maintenance bars in the 13″ length introduced by Buckeye that cuts to size with a minimum of waste — Buckeye graphited bearings — and Buckeye "Specials" in a wide variety of IDs, ODs and lengths to customers' blueprint in any desired bearing metal analysis, slotted, split, drilled or threaded, with or without lugs, flanges, collars, etc., do more than meet mere dimensional requirements.

Buckeye are quality bearings — at standard prices — capable of giving a maximum of long, efficient trouble-free service.

The outstanding performance of these bearings results from Buckeye's skilful, experienced and painstaking manufacture. Through the use of virgin metals only, impurities in Buckeye bearings are held to negligible limits—and the complete laboratory and metallurgical control maintained over charging ratios, melting and pouring temperatures, and all other manufacturing processes assures the production of an exceedingly high quality of product—free from porosity—each piece of which month after month measures up fully to Buckeye's exacting specifications.

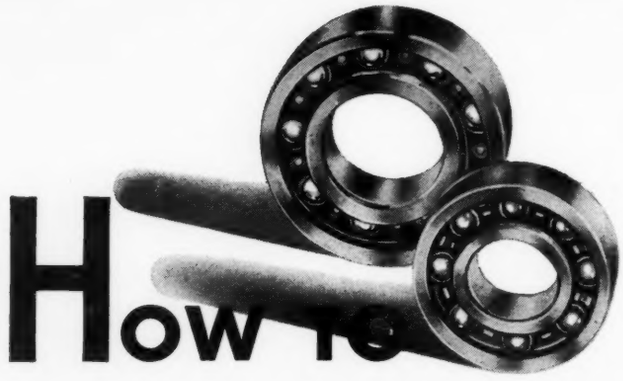
No order is too big or too small for Buckeye.

Buckeye
BRASS AND MANUFACTURING COMPANY

BRONZESMITHS SINCE 1900

6412 HAWTHORNE AVE. CLEVELAND, OHIO

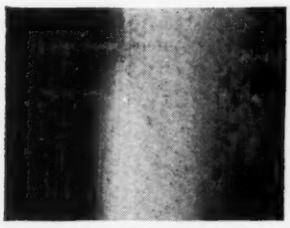
BRONZE SLEEVE BEARINGS • STANDARD SIZES OR TO CUSTOMERS' BLUEPRINT IN ANY RECOGNIZED BEARING METAL ANALYSIS



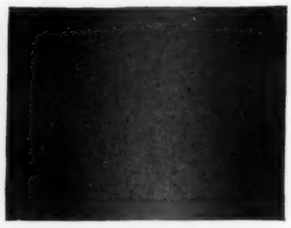
How to KEEP BEARINGS ROLLING

Abrasive metal particles that are constantly forming in the lubricant are the greatest cause of excessive wear to costly bearings. Low cost Magnetic Drain Plugs prolong the life of bearings by removing this abrasive matter. A powerful, permanent magnet catches and holds all ferrous metal —keeps it out of circulation—and thus eliminates a major cause of bearing failure.

Photo shows cluster of metal particles removed from gear case.



Microphoto shows section of raceway damaged by abrasive metal flakes.



This microphoto shows how a bearing raceway should look.

If you can provide an A-1-J Priority rating, we can supply you with Magnetic Plugs *now!* But in any case, we'll be glad to supply you with interesting data suggesting applications for your future products.

LISLE CORPORATION
BOX 1033 • CLARINDA, IOWA

Magnetic DRAIN PLUGS

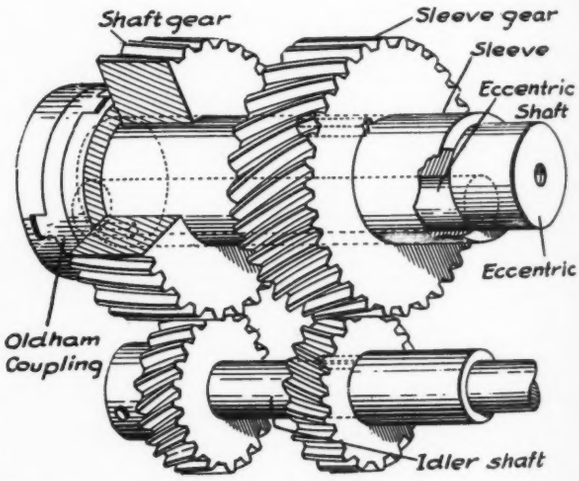
roll diameter is smallest.

When rewinding at high speed maximum power is available at the reel mount because the speed-controlled brake no longer operates, being coupled through an over-running clutch which does not drive when the direction of rotation is reversed.

Eccentric Has Variable Throw

VARIABLE stroke for toggle presses and similar mechanisms is obtained through the use of a patent assigned recently to United Shoe Machinery Corp.

Power applied through a pinion not shown in the illustration drives a shaft gear which is mounted freely on a sleeve running in bearings. The sleeve has an eccentric bore carrying a shaft on the end of which is an eccentric with a throw equal to the eccentricity of the sleeve bore. Normally, as in the illustration, the eccentric and the outside of the sleeve are concentric; thus the effective throw of the eccentric is zero. The eccentric shaft is driven through an oldham coupling, one element of which is integral with the shaft gear. Keyed to the sleeve is a gear driven by the shaft gear through right and



Sliding the idler pinions changes the phase of eccentric shaft and sleeve

left-hand helical pinions on an idler shaft. Normally the shaft and sleeve rotate as a whole.

When it is desired to operate the press, the idler shaft is moved to the right by means of a shifter. Because of the opposite helices on the two pinions and their respective gears the sleeve gear is rotated counterclockwise with respect to the shaft gear. As a result the eccentric moves away from its position concentric with the sleeve and actuates the press. The effective throw of the eccentric is controlled by the amount of axial movement of the idler shaft.

By causing the idler shaft to move to the right and left during a single rotation of the shaft gear it is possible to obtain a single stroke at a time without stopping the driving motor. Relatively

NAVY "E" AWARDED TO DE LAVAL

In the United States Navy, the highest of all honors is the Navy "E", the emblem of excellence awarded for supremacy in gunnery, communications and engineering.

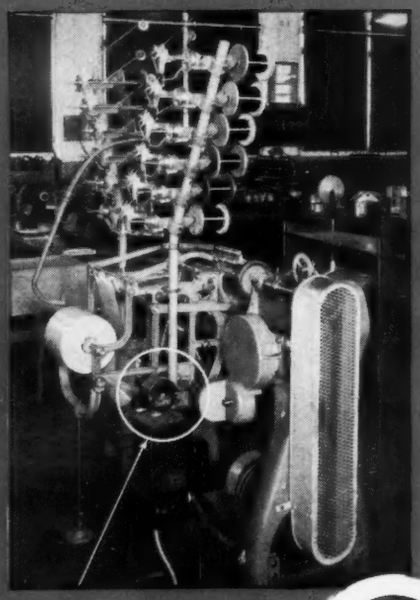
Until recently the Navy "E" has been restricted to personnel of the United States Navy.

By special permission of Franklin D. Roosevelt, President of the United States, and Frank Knox, Secretary of the Navy, the Navy has awarded the Navy "E" to the De Laval Steam Turbine Company for outstanding excellence in industrial production.

The De Laval plant at Trenton, New Jersey, is now permitted to fly the All-Navy burgee, while each employee has received the special Navy "E" lapel insignia in evidence of a job "WELL DONE".

DE LAVAL STEAM TURBINE CO.
DE LAVAL
TRADE MARK
TRENTON, N.J.

Time Meters Can Make Your Machines More Productive



G-E time meter (Type KT) on coil-winding machine

HERE'S HOW - -

1. A machine can be idle part of the time and go undetected. But a time meter—to measure machine use—will spot it. Then a changed schedule of work will utilize the machine more effectively.

2. Time meters will tell your customers when to service equipment. This avoids costly delays and shutdowns.

Time Meters Help YOU, Too

By enabling your customers to so schedule work that machines are utilized to full capacity, time meters can help to avoid the purchase of additional equipment that's not actually needed. This may enable you to supply one machine instead of two. Thus, you can spread your production among more customers. That's important today!

G-E time meters are available for conduit, panel, or switchboard mounting. Telechron motor timed, they are dependable and accurate. For additional information, ask your G-E office for "Metered Time" (GEA-1574) and Bulletin GEA-3299. *General Electric, Schenectady, N. Y.*

General Electric and its employees are proud of the Navy award of Excellence made to its Erie Works for the manufacture of naval ordnance.

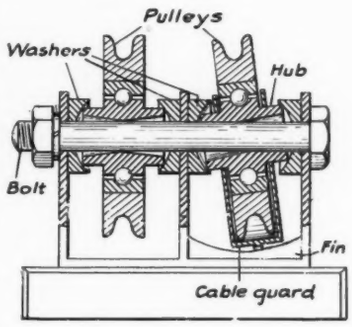
GENERAL ELECTRIC

small force is required to move the idler shaft, since the power to operate the press does not pass through the idler gears.

Guide Pulleys Are Adjustable

GUIDE pulleys for control cables must be accurately mounted to insure perfect alignment between the rotational axis of the pulley and the plane passing through the cable runs. Proper setting of fixed mountings is time-consuming, an objection which is overcome by an adjustable mounting described in a patent assigned to Curtiss-Wright Corp.

Adaptable for single pulley or for gang assembly the mounting for each pulley comprises a hub or inner race with a double tapered bore, about which the pulley itself revolves on a ball bearing. The ends of the hub fit against washers with concave spherical faces. Smallest diameter of the hub bore



Fixed inner race and concave washers facilitate pulley alignment

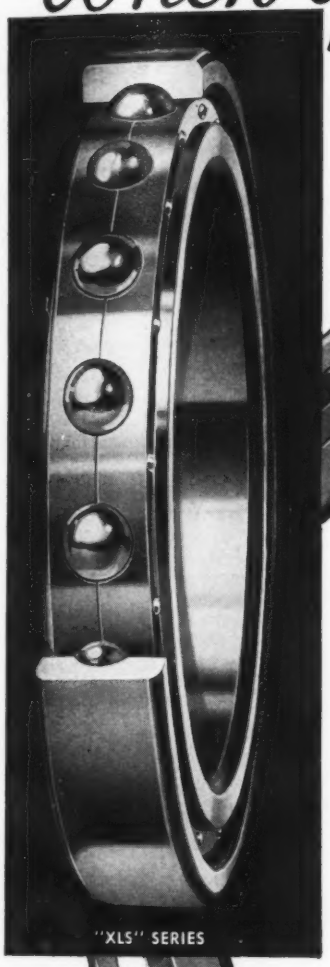
fits snugly over a bolt serving as a support. When the pulleys have been accurately aligned the bolt is tightened, clamping the hub securely in the intended position. Readjustment is quickly made by loosening the bolt and tilting the pulley the necessary amount within the limits permitted by the taper of the bore.

Pulley may be provided with a cable guard as shown on the right of the illustration. The guard is prevented from turning and fouling the cable by two fingers which straddle a fin forming part of the fixed mounting bracket.

PRODUCTION of Flying Fortresses under the Boeing-Vega-Douglas pooled facilities program has been advanced through the use of an electrolytic transfer process, patented by Lockheed, by which the master pattern or work template can be reproduced in five minutes. The original drawing first must be scribed on a specially-treated metal sheet to make the master layout which then can be electrolytically transferred to an inexpensive metal copy sheet from which the work template is cut. Total cost of template layout copying by this new method, including labor and materials, has been found to be less than ten cents per square foot of layout area, as contrasted with one dollar per square foot by hand.

When You're Cramped for Space

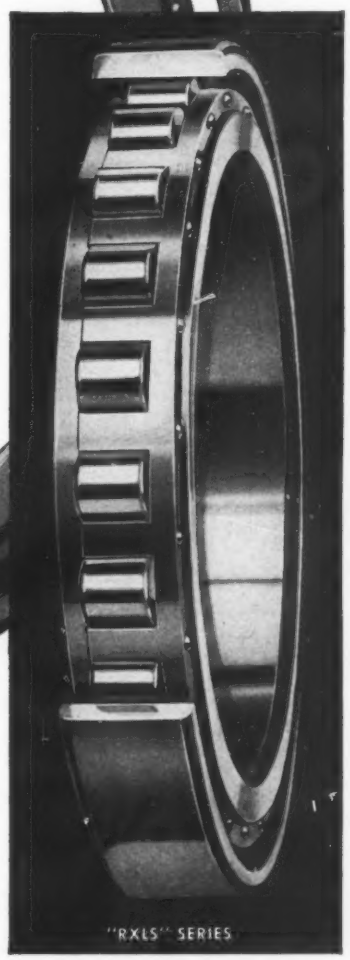
USE THESE VERY LIGHT INCH SERIES BEARINGS



HAVING bores abnormally large, as compared with the outside diameter, they offer definite advantages under certain conditions found in machine design. You may have them in several different types, *affording compactness, light weight, and greater latitude in your design.*

There are several lines of very light type ball bearings, which include the "S" starting at 1/8" bore, and the "XLS" starting at 1 3/8" bore, running up to a maximum of 21" bore and 28" outside diameter. And in very light type roller bearings, there is the "RXLS" Series, paralleling the "XLS" in size range.

Why not let our engineers tell you more about these Very Light Precision Bearings? Write for the Catalog.



"NORMA-HOFFMANN"

PRECISION BALL, ROLLER AND THRUST BEARINGS

NORMA-HOFFMANN BEARINGS CORP'N.—STAMFORD, CONN., U. S. A.

Use OVERLAY Gibsiloy ELECTRICAL CONTACTS
For Economy... And BETTER PERFORMANCE

Sample of nested stamping of Gibsiloy Overlay, showing savings of metal.

★ These contacts are available in laminated metals in which Gibsiloy materials and base metals are combined to obtain the best features of each (Gibsiloy for its electrical properties and base metals for their mechanical properties).

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(*Continued from Page 67*)

teeth of a standardized file are pushed across the piece to be tested. If the work is as hard or harder than the file, it slides easily; otherwise, there is an appreciable resistance. The use of this test requires considerable skill and is affected by many variables. Results are not reproducible in different plants. It is useful for control of quantity products where the tester acquires the needed skill. For infrequent testing it is not satisfactory (21).

The brinell and rockwell tests are interchangeable on sections over about ¼-inch in thickness and on hardnesses up to 600 brinell. On sections under ¼-inch the rockwell is preferred because the lighter loads and shallower impressions eliminate anvil effect. The rockwell is preferable on hardnesses above 600 brinell because the friction of the penetrator renders the brinell unreliable. The scleroscope may be applied to the entire hardness range of ferrous materials, to fairly thin articles, and to very large equipment. Its results are, however, not as reliable as the brinell or rockwell. *Fig.* 7 shows the indentation of various tests made on the same test block. It will give an idea of the relative sizes. On harder material all impressions will be less, but the relative picture will be substantially unchanged. From this it is apparent that the brinell test would be best for a rough surface averaging over the material.

In closing the general discussion of hardness tests, a unique method of measuring hardness of very thin surfaces such as plating, etc., by dropping grains of sand and observing the reduction in light reflectivity, is described in Reference 22.

Fail Under Repeated Stress

It is common knowledge among designers today that materials may fail under continually repeated stresses at levels well below the elastic limit. To determine this fatigue-failure stress, a variety of testing machines have been developed (7, appendix 3) and (23). Of these, the "rotating beam" type, revolving a cylindrical specimen under uniform bending moment, is probably the most common.

Illustrated in *Fig.* 8 are some typical stress versus number of applications, *S-N* curves. The stress level at the flattened out portion is known as the "endurance limit". In steels, at least, there is reason to believe this stress level can be borne indefinitely. It will be found at as low as 500,000 applications or reversals on very hard steels and up to 10,000,000 on soft steels. With other than ferrous materials a much larger number is required, most light metals requiring at least 500,000,000. Even there, one cannot be sure that an indefinite endurance limit has been reached. From these curves it is apparent that a part that is to be loaded relatively few times may employ a much

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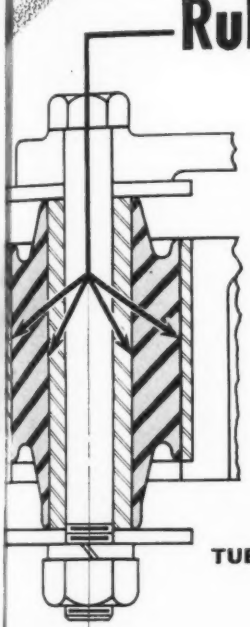

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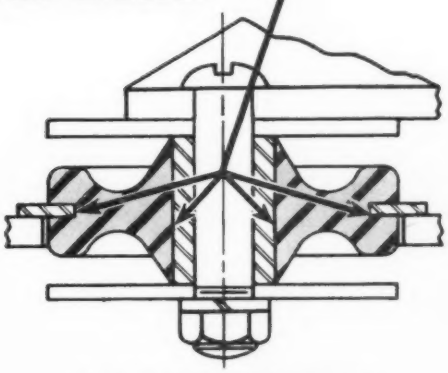

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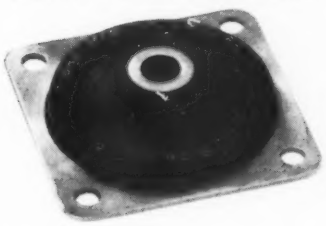

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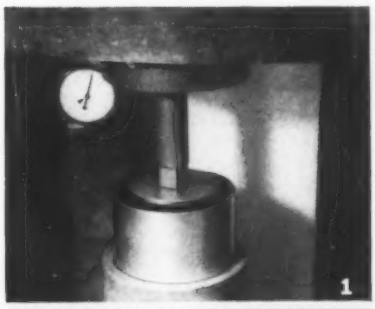

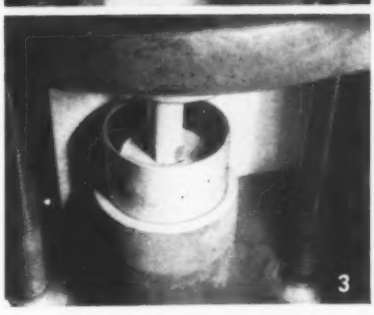

The above tests were made using a Lord Tube Form Mounting 5½" O.D. x 4½". Figure one shows mounting under no load. Figure two shows mounting stressed in shear under its rated load of 2,200 lbs. Center sleeve is depressed 1/16". Figure three shows same mounting under 50,000 lb. load (press capacity). Center sleeve is depressed 1-13/16" and shows no failure of rubber-to-metal bond, even with more than 2000% overload.

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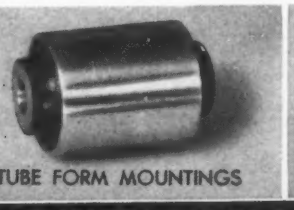

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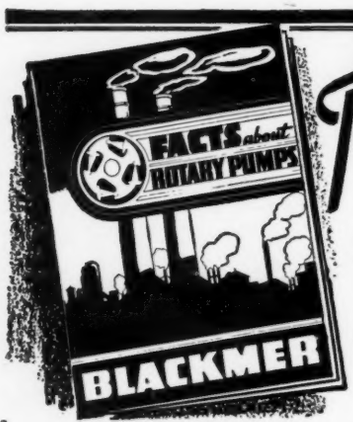

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higher stress than one having a large number of applications. By taking advantage of this the designer can conserve considerable material.

The curves in *Fig.* 8 are based upon equally-reversed stress. Tests made where the reversed stress is reduced show much higher failure values, particularly when the reversed stress is zero or positive (24). The designer should take advantage of this factor also, where load conditions will permit.

The endurance limit cannot be related exactly to any other physical characteristic. For steels it runs, roughly, about one-half the ultimate; but this is by no means exact. There does not seem to be any well-founded reason for believing that any one steel composition, when heat treated to the same ultimate, is apprecibly better or poorer than any other. The difference seems to be more in the metallographical characteristics of the material, the presence of dirt, directional effects from rolling, nonuniform grain size and a host of other things of this nature.

Stress Raisers Affect Results

Usually a fatigue test uses smooth, highly polished specimens. Any roughness of the surface, notches, dirt inclusions, or nonuniform grain cause a concentration and raise the stress developed in the material under a given loading. Since, in the conventional method of figuring, no account is taken of these stress raisers, the piece fails at a lower "nominal" stress. It should be noted that the actual stress developed in the piece is greater than the stress figured by conventional methods. In other words, it is technically an error to say that the unpolished specimen failed at a lower stress. Instead, the statement should be qualified to say that, *figured by conventional methods,* the stress in the unpolished specimen is lower than the stress in the polished piece. This viewpoint is important in attempting to correlate stress concentration data.

It should also be mentioned that the stress at points of high concentration is never as great in the actual metal part, as theory would indicate. That is, the stress concentration factor, as calculated by elastic theory or photoelastic analysis, is greater than the factor determined experimentally. It is probable that minute plastic flow at points of high stress concentration occurs without causing failure of the material. This results in a stress adjustment, reducing it below the theoretical value (12 and 25). This is the kind of ductility that would be desirable to measure, but not, apparently, the one obtained from the tensile test.

It is now obvious that one of the missing links in the functional tests is the measure of the ability of a material to adjust itself at stress concentrations. With this factor the stress peak could be determined by elastic theory, photoelastic analysis, etc., and the "stress-relief factor" used to calcu-

(*Continued on Page* 156)

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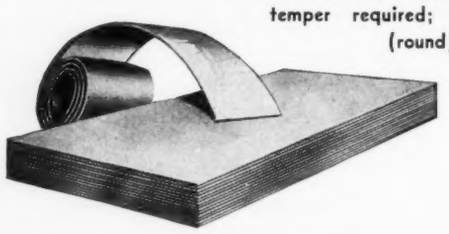

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(*Continued from Page* 150)

late the stress actually developed. This figure could then be compared with the endurance limit as determined on polished specimens. In the interim, however, it is necessary to rely upon experience, judgment, or just plain guessing to tell which material is better in this regard than others.

Many excellent contributions have been made to the subject of fatigue. It is strongly recommended that the reader peruse references, in particular the volume of Battelle (7). It includes an extensive bibliography.

Commonly a high "impact" value is demanded of steels to obtain the ability to resist shock loads. Actually, if the inertia effect is taken into account in calculating the loading, there is reason to believe that a suddenly developed stress may be more safely borne than a steady one. While there is probably a critical velocity of loading at which a shattering fracture may occur, this velocity is rarely exceeded on any steels except those in a very poor metallurgical condition, or in the presence of a severe notch. Even the impact of a bullet will cause a ductile failure in a ductile material (Hoyt in Reference 27). What the usual impact test measures is the relation between the cohesive and the shear strength of a test specimen.

Defines Terms of Strength

The "cohesive strength" of a material may be defined as its resistance to the separation of its atoms, and the "shear strength" as the resistance to a distortion of the atomic space lattice. It is reasonable to suppose that failure from the first is due to tensile stress and from the second to shear. Now, if failure is from the first it will be sudden (brittle) and little energy will be absorbed. If failure is from the second it will be ductile, absorbing a large amount of energy. Failure may also start by shear, the material work hardening and then failing in cohesion. Examples of broken test specimens are shown in *Fig.* 1.

It is apparent that since the shape of the specimen will materially affect the relationship between the stresses it will also materially affect the energy absorbed, there being little correlation between the various tests. If the test is to have any value at all, then, the specimen should vary to suit the material, with the attempt to secure failure in the last-described fashion. In this connection, the comparison between values for double-width specimens and the standard single would appear to offer considerable value (Riegel and Vaugh in Reference 27). There is also an important temperature effect, changing the strength relationship of the material (Hoyt in Reference 27).

This subject is too vast to cover in a few words. The reader is referred in particular to Reference 27 for discussion and to ASTM E23-41T for the standardized charpy and izod test. It would appear that an important phase of this matter to

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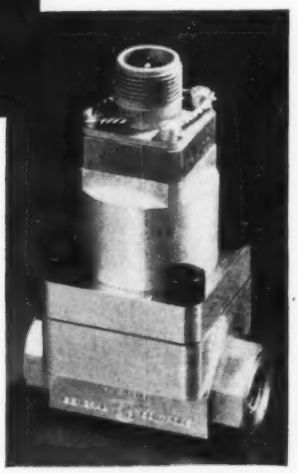

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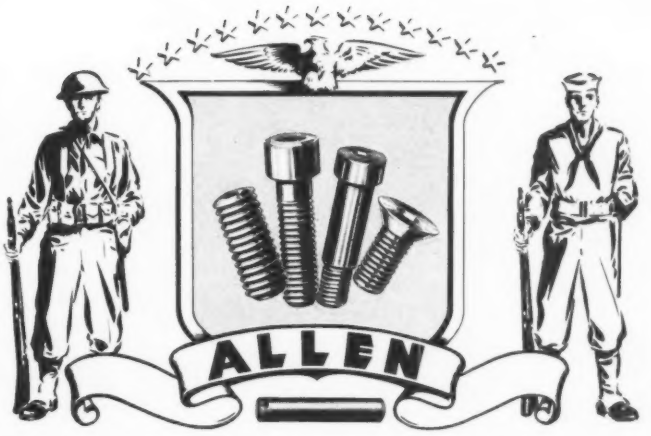

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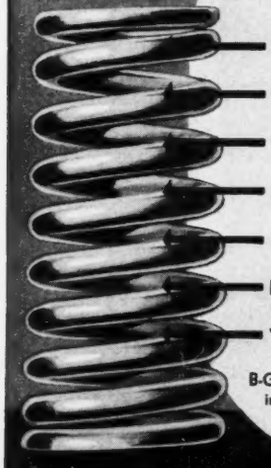

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which too little attention is given is "utility" testing on the parts, or a facsimile of the parts, actually used (Tour in Reference 27).

Creep is a functional test of importance where high temperatures are involved. Tests for this have but recently been standardized, as covered in ASTM E21-37T and E22-41. Since this important phenomenon holds specialized interest, the reader is referred also to References 4, 5 and 6.

The list and discussion of specialized tests would fill a volume. They are generally developed for particular purposes, such as the majority of wear tests, corrosion tests, low temperature tests, abrasion, damping, vibration, cupping, machining, and so on. Each is a subject in itself and cannot be covered in this article.

This concludes the general discussion of physical testing. The next articles in this series will enter into the constitution of iron and steel, how it is affected by composition and heat treatment, and what the effect is on the functional characteristics of the material.

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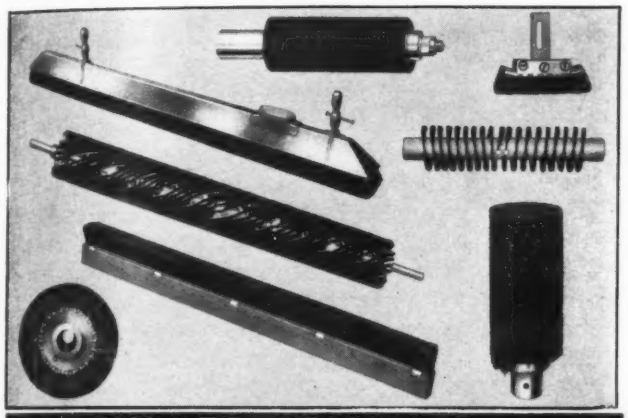

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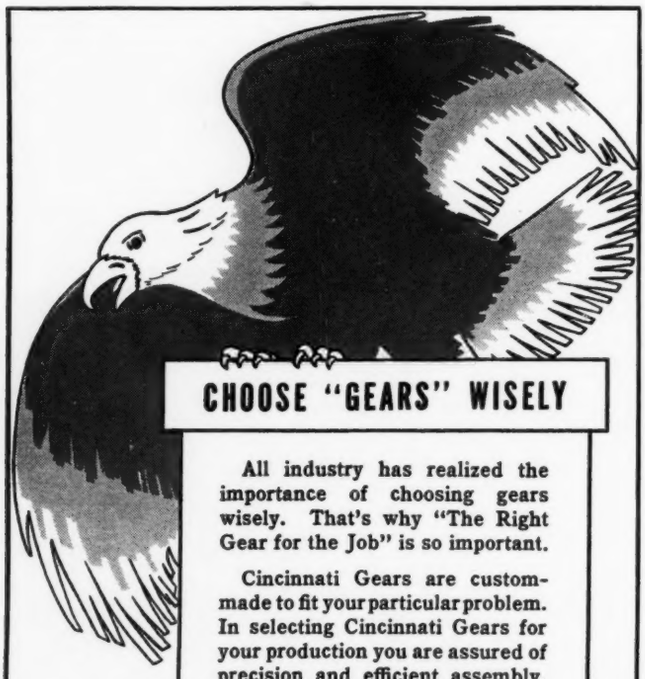

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Shrink-Fit Assemblies

(*Concluded from Page* 83)

value for the stress concentration factor and the corrosion factor can be selected. Subtracting these factors in an appropriate manner from the test results on press-fit assemblies, the influence of the combined stress effect can be evaluated. This value can then be compared with that found by the theory used in this paper[7].

This comparison between the test results and the proposed strain-energy theory is best summarized by representing the plotted results as shown in *Fig.* 23. In this graph, based on tests by Messrs. Peterson and Wahl at Westinghouse, the shrink-fit pressure X is plotted horizontally and the combined stress concentration factor vertically. This stress concentration factor includes the three modifying influences of rubbing corrosion, three-dimensional stress and the usual stress concentration factor. The four test values for this combined stress concentration factor are plotted in *Fig.* 23 for both the ordinary type shrink-fit and the "grooved" type indicated in *Fig.* 15. A comparison of the test results with the theoretical values shows good agreement between experimental and theoretical results.

Tests Show Agreement with Theory

Other types of shrink-fit specimens with end fillets and with center cuts were tested by Peterson and Wahl and an interpretation of these results in terms of the proposed theory also shows good agreement. Additional supporting data not presented in this paper are a number of test results obtained by Thum and Wunderlich[8]. These tests were performed on medium carbon steel specimens with the press-fit pressure applied by a low carbon steel collar. Various types of specimens tested by Peterson and Wahl were also considered by Thum and Wunderlich. The types of fits used in these experiments are shown in *Fig.* 24. It should be emphasized that in the interpretation of the test results shown in *Fig.* 23, certain approximations were made in assuming that the usual stress concentration effect and the rubbing corrosion factor remained the same irrespective of the combined stress values. However, the interpretation shows that the strain-energy theory affords a good approximation.

This article has presented design information for shrink-fit assemblies subject to fatigue stresses. In using the results, however, allowance must be made for the effects of stress concentration, impact loads and high temperatures. Other conditions of service and construction not covered by the idealized case considered should be noted also. The analysis, however, considers the important combined fatigue stress effect, not adequately covered in previous studies.

[7] These calculations were made by J. A. Sauer in a Master's Thesis performed under the writer's direction.

[8] "Der Einfluss von Einspann und Kraftangeffstellen auf die Daverhaltbarkeit der Konstrucktionen", Zeit. *V.D.I.*, Vol. 77, 1933.

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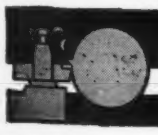

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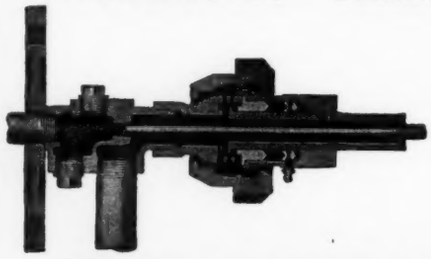

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Which Thermostat?

(*Concluded from Page 77*)

temperatures; life is longer than for iron-constantan.

Resistance thermometers using nickel windings are recommended for relatively low temperatures requiring high degree of accuracy between —100 and 300 degrees Fahr. Platinum windings increase the accuracy and also the operating range. Advantages of these units include greater inherent accuracy than other types, long allowable distance between bulb and recorder and high dependability. Basic principle utilizes the phenomenon that resistance of a conductor increases with temperature. Therefore a metal is selected to have a high temperature coefficient of resistivity that remains constant throughout the life of the unit. Platinum or nickel wire is usually employed and wound on a spool in such a way as to minimize strains due to temperature change.

High Accuracy Is Available

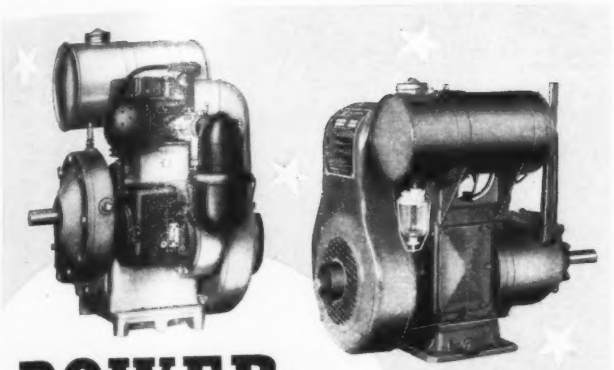
With platinum windings accuracies of ±.02-degree are possible in the usual operating ranges and ±5 degrees for temperatures up to 1800 degrees Fahr. When nickel is used, ±.3-degree is obtained in its operating range of —150 to 300 degrees. Steel tubing is the usual protecting tube for the bulb and the same considerations affecting application of thermocouples are generally applicable to resistance type bulbs.

To reduce errors a proper method of installing separable bulb sockets is illustrated in *Fig.* 7. When possible insulation should be removed to allow placement of the socket close to the wall. Insulation should be replaced over the socket as indicated. Lagging extension causing exposure of metal parts and socket length should be avoided wherever possible to reduce error in temperature reading.

For extremely high temperatures, there are two types of pyrometers that are useful for indicating, recording or automatic control. They are the photoelectric-optical type utilizing two phototubes and the radiation-pyrometer type which makes use of a thermocouple to measure the radiant energy emanating from the hot body. Both types involve lens systems or mirrors with fixed apertures. Millivoltmeters or potentiometers are used with these pyrometers, as with the thermoelectric types.

Pressure bulb systems of both the coil and bellows types are too involved to cover in this article and will therefore be treated in the second part of the series to be published next month.

Co-operation of the following companies for generously supplying information for this article is acknowledged: The Bristol Co., *Fig.* 1; The Brown Instrument Co., *Figs.* 2, 6, and 7; W. M. Chace Co., *Fig.* 3; Cook Electric Co., Thomas A. Edison, Inc.; The Foxboro Co.; Julien P. Friez & Sons; Penn Electric Switch Co.; Robertshaw Thermostat Co.; Spencer Thermostat Co.; Westinghouse Electric & Mfg. Co., *Figs.* 4 and 5; Wheelco Instruments Co. The extensive collaboration of The Brown Instrument Co. was especially noteworthy.



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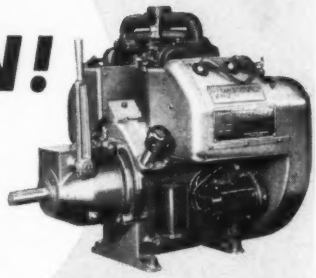

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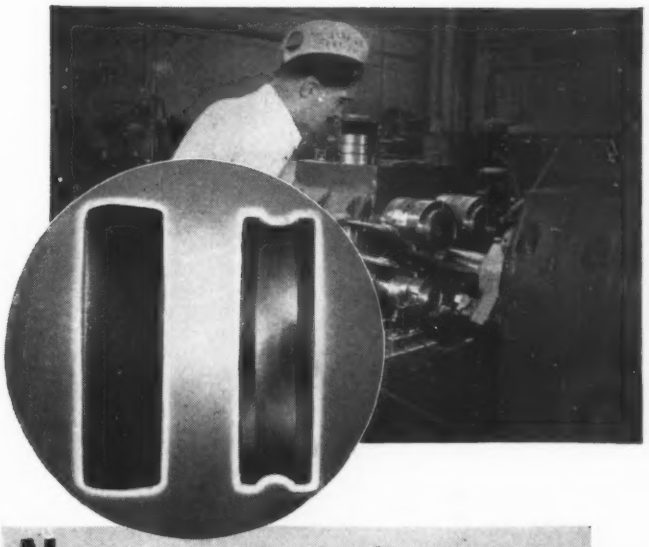

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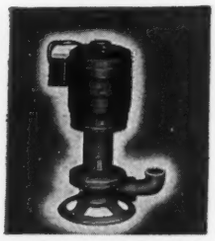

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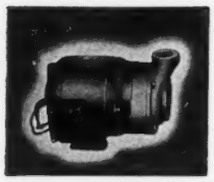

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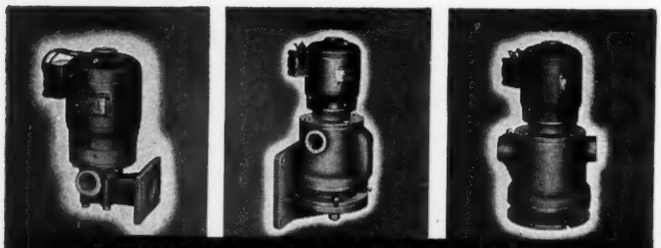

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Bearing Seizure Affected by Surface Finish

(*Continued from Page* 84)

chine, which has been found to give results in accord with service data if a proper test procedure is followed. A desirable feature of this machine is that the friction rises smoothly and steadily with increasing load in the region where seizure is imminent.

Load is applied in increments according to a set schedule until the frictional torque reaches four kilogram-centimeters. The load necessary to produce this torque, the "Initial Seizure Load," is a measure of the seizure-resisting quality of the original shaft finish before wearing-in has caused any appreciable change. For a two-hour period following the initial loading the torque is maintained at four kilogram-centimeters by adjustments of the load. Since the load-carrying ability of the shaft improves during this time, it is necessary to increase the load to maintain the torque at four kilogram-centimeters. Load on the bearing at the end of this two-hour period, the "Final Seizure load," is a measure of the seizure-resisting quality of the shaft surface after a moderate amount of wearing-in.

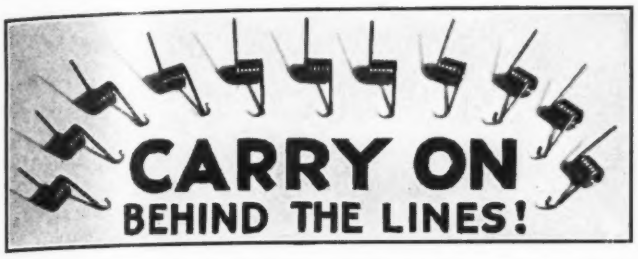
Results for Steel Specimens

Type of Finish	Profilometer (rms microinch) Axial	Profilometer (rms microinch) Circum.	Product of Profilometer Readings	Average Seizure Load Initial	Average Seizure Load Final	Average Wear (mg)
Fine sandpapered..	1.5	1.0	1.5	169	226	0
Fine ground	1.5	.5	.75	144	208	2
Fine hyprolapped...	2.5	2.5	6	138	143	0
Medium sandpapered	5.0	2.0	10	121	198	1
Fine loose-abrasive lapped	3.0	3.0	9	70	98	1
Medium hyprolapped	3.5	3.5	12	47	67	3
Medium ground.....	6.0	2.5	15	41	74	5
Medium loose-abrasive (ring) lapped	4.5	3.5	15	38	..	15*
Rough ground.....	10.0	4.0	40	37	45	5
Medium loose-abrasive lapped.....	3.5	3.5	12	35	49	11
Rough sandpapered	8.0	3.5	28	30	50	24

*Average wear during short tests up to and including galling.

Shapes of typical coefficient of friction versus load curves are shown in *Fig.* 1, one curve representing a rough surface and the other a smooth surface. A torque of four kilogram-centimeters for defining the seizure loads was chosen because it is high enough to be in the region of incipient seizure but not so high that damage to the shaft or bearing will result.

Studies with four different bearing materials were made for the purpose of selecting one material for use in the more extensive study. Tests of a few different ground and sandpapered surfaces on steel shafts were made on each of the four bearing alloys. The results show that the type of finish on the shaft is a factor that markedly affects the load-carrying ability of bearings, though babbitt bearings



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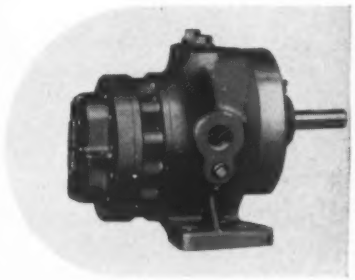

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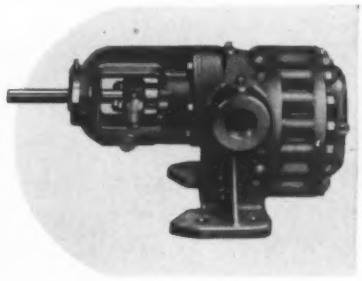

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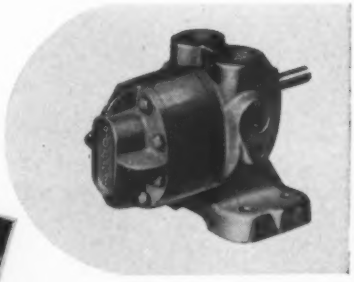

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appear to be relatively insensitive to the effect of finish.

Silver is highly sensitive to finish but is so seizure-resistant that on good surfaces the final seizure loads are higher than the load limit of the machine. Hard bronze appears to be quite sensitive to the effects of finish, but it is not a particularly seizure-resistant material.

Bearings of copper-lead were chosen as being most suitable for a more extensive study, since this material is sensitive to the surface finish on the shaft and has a high seizure resistance which is usually within the load limit of the machine. Moreover, it is a material that finds considerable use in aircraft master-rod and main bearings as well as in other high-speed, heavily loaded bearings where seizure is a factor.

When the seizure test results are plotted against the axial profilometer readings, neither the initial seizure loads nor the final seizure loads show good correlation with the conventional axial profilometer readings when all of the data are considered.

Somewhat better correlation is found between the seizure loads and the product of the profilometer readings taken in the axial and circumferential directions. *Fig.* 2 gives an indication of how good this correlation is. The average deviation of the initial seizure-load points from the best curve is about 10 per cent, an error which is less than the reproducibility of either the seizure-load measurements or the individual profilometer readings. The average deviation when the seizure results are plotted against axial roughness alone is about twice the above value, 19 per cent.

The difference between the final and initial seizure loads is a measure of the ability of the finish to wear-in rapidly to a better surface. Fine ground and the fine and medium sandpapered surfaces all wore in rapidly to surfaces having much higher resistance to seizure. The fine hypro-lapped surface, on the other hand, wore-in very slightly, and the other surfaces wore-in by intermediate amounts.

One might well ask if the improvement in load-carrying ability, which has been attributed to the wearing-in of the shaft, is not an improvement of the shaft-bearing combination. Strictly speaking, this is true, but there are reasons to believe that the contribution of the softer bearing metal during wearing-in is practically negligible. The bearing does, of course, experience wear of measurable amounts which are roughly dependent on the roughness of the shaft, as the table shows, whereas the wear of the shaft is too small to measure. Wearing the bearing, however, does not improve its surface because its micro-contour is determined solely by the micro-roughness of the shaft. Only as the shaft becomes smoother does the surface of the bearing improve.

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Also valuable information on Available Manufacturing Facilities

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Business and Sales Briefs

HERETOFORE in the engineering and sales department of Cutler-Hammer Inc., Milwaukee, R. Keeler has been transferred to the Philadelphia office. J. E. McSorley, associated with the resales division, has been transferred to the Cincinnati district office, while J. A. Darnall is now connected with the New York district office. The latter was formerly in the sales department at Milwaukee.

♦

William M. Black has been made a vice president of American Brake Shoe & Foundry Co. Since 1940 Mr. Black has been president of American Manganese Steel division of American Brake Shoe & Foundry, Chicago Heights, Ill. He joined this division in 1912, becoming general sales manager in 1934 and a year later, vice president.

♦

M. B. Leidy is now Philadelphia district sales manager for Latrobe Electric Steel Co.

♦

In the Pacific coast area, James H. Hoghland has been named sales engineer for American Screw Co., Providence, R. I. He will be located at 1724 North Vista street, Hollywood, Calif., and will supplement the efforts of K. T. Jackson who has been covering the entire territory for the company.

♦

With headquarters at 3801 College avenue, Indianapolis, Robert H. Pyle will act as district representative for McKenna Metals Co., Latrobe, Pa., in southern Indiana.

♦

For twenty years as employe of Westinghouse Electric & Mfg. Co., George H. McBride has been appointed sales manager of the gearing department to fill the vacancy created by Newbold C. Goin who recently left the company to become manager-secretary of the American Gear Manufacturers association.

♦

A. C. Martinelli, who was active in sales for Monsanto Co. in the New Jersey territory, has been promoted to assistant manager of the Monsanto Plastics division, New York sales office.

♦

Appointment has been made of Harold P. Blum as Cleveland territory representative for Metal & Thermit Corp. He will continue to represent Una Welding Inc.

♦

Previously in the New York office of Square D Co., C. T. Nash has been placed in charge of the new Springfield, Mass., branch office of the company.

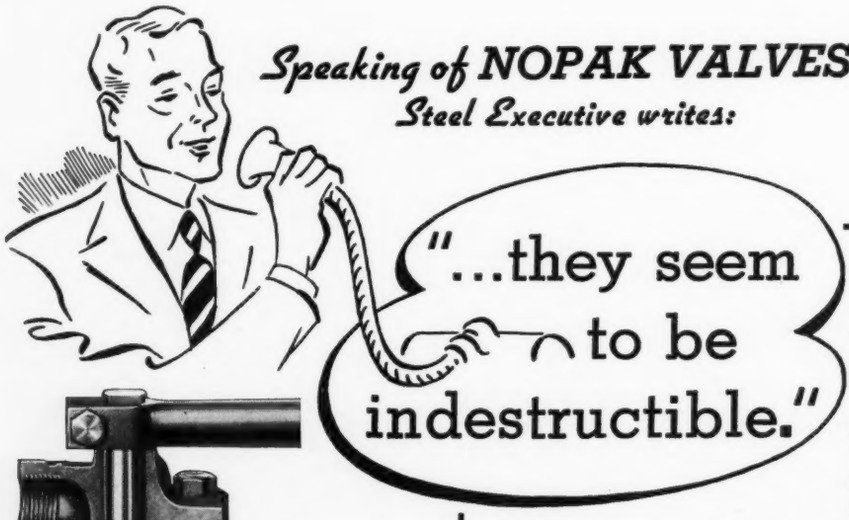
♦

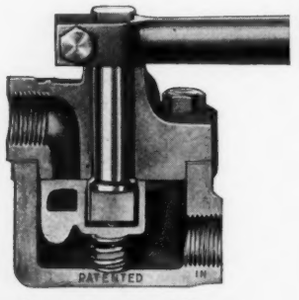
At the Rockford, Ill., plant of the Twin Disc Clutch Co., new machines and facilities are being installed and a considerable increase in the number of employes will take place shortly due to the creation of a separate division of the company to handle the development, production and sales of hydraulic drives and torque converters. This was formerly a depart-

(*Concluded on Page* 174)

Speaking of **NOPAK VALVES**

Steel Executive writes:





Cross-Sectional View, NOPAK 3- and 4-Way Valve. Simple design, rugged construction, *packless* assembly, and the famous NOPAK Bridged-Disc Principle make NOPAK Valves leakproof and wear-proof. Perfectly lapped, leakproof sealing surfaces of disc and seat improve with use . . . are constantly shielded from grit abrasion.

● In May, 1927, t venty-two NOPAK Valves were installed on air pressure lines in the Worden-Allen Co. plant. On May 1, 1929, the plant superintendent reported: "All valves O.K., will not flicker a match." On July 11, 1931: " . . . every valve tested and found in perfect shape. No repairs or adjustments of any sort . . . since original installation."

After fifteen years, March 23, 1942, the company's president wrote regarding original installation and subsequent purchases:-" . . . . all valves still in service, except where air pipes have been removed . . . they seem to be indestructible."

Design engineers, you can build the same high type of valve performance and service into your product by writing NOPAK into your specifications. Long lived, trouble-free valve operation, lifetime protection against air or pressure loss, easy, rapid manipulation, and precision control of air or hydraulic power are typical NOPAK features. Write for Bulletin 84.

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A 3784-½H-B

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AIR EQUIPMENT

AS APPLIED TO LIPE CARBO-LATHE

1 "LOGAN" Model "R" Air Cylinder

2 "LOGAN" Reducing Valve and Air Filter Unit

3 "LOGAN" Model "P" Air Control Valve

4 "LOGAN" Parallel Grip Collet Chuck

This Lipe Carbo-Lathe is tooled for turning armor piercing projectiles. The headstock is equipped with a *"LOGAN"* Model "R" Rotating Type Air Cylinder for the operation of a *"LOGAN"* Compensating Type, Parallel Grip Collet Chuck. This Cylinder is operated by a *"LOGAN"* Model "P" Poppet Type Hand Control Valve. In addition, this Carbo-Lathe is equipped with a *"LOGAN"* Reducing Valve, Automatic Lubricator and Air Filter Unit. *"LOGAN"* Sales Representatives and *"LOGAN"* Engineers will be glad to make recommendations on your production problems.

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911 PAYSON ROAD LOGANSPORT, INDIANA

Manufacturers of Air and Hydraulic Devices, Chucks, Cylinders, Valves, Presses and Accessories

(*Concluded from Page* 168)

ment of the company's operations at Racine, Wis. R. M. Schaefer has been named vice president in charge of the hydraulic division.

♦

Copperweld Steel Co., Glassport, Pa., has appointed N. H. Brodell metallurgical sales engineer.

♦

Benjamin Sack has been elected president of Aircraft Screw Products Co. Inc., Long Island City, N. Y., to fill a vacancy created in 1941. Formerly he was executive vice president of the company.

♦

With a ground-breaking ceremony, construction was recently started on the new government-financed National Aluminum Cylinder Head Co., at Cleveland, O., subsidiary of The National Bronze & Aluminum Foundry Co. Upon its completion early next year the plant will produce aluminum castings for aircraft engines and employ more than 1500 people.

♦

In the industrial finishes division Herschel E. Post has been made general sales manager by Pittsburgh Plate Glass Co., with headquarters in Pittsburgh.

♦

Former vice president and general manager of Bridgeport Brass Co., Herman W. Steinkraus now is president. He retains his post as general manager of the company.

♦

In order to step up deliveries, Onsrud Machine Works Inc. has enlarged its plant. Recently an entirely new west wing was added, and the roof has now been raised to add another floor. Total increase of floor space will result in a production capacity almost twice as great as before, and deliveries can now be made almost within normal periods of time.

♦

Formerly vice president and works manager, G. C. Gridley has been made president and general manager of the Mechanics Universal Joint division of Borg-Warner Corp., Rockford, Ill. He succeeds E. C. Traner. R. R. Rolph is vice president and director of sales.

♦

Promotion of W. R. Kuhn from assistant district manager to district manager of Allegheny Ludlum Steel corporation's Cleveland office has been announced.

♦

On the merger of the Pittsburgh office with the Detroit and Cleveland offices, William G. Hassel has been made manager of the Detroit office of Crucible Steel Co. He was formerly manager of the Pittsburgh office.

♦

Announcement of the appointment of Robert Borchedt as sales manager has been made by Arens Controls Inc., 2253 South Halsted street, Chicago, manufacturers of remote controls. Mr. Borchedt came to the company from Bell Aircraft where he was manager for the airplane section of the contract division. The company has also announced the opening of a western sales office, at 245 East Olive street, Burbank, Calif., where it will be represented by W. W. White.

♦

Appointment of L. W. Brashares as manager of the Cincinnati district, has been announced by American Rolling Mill Co., Middletown, O. E. D. Dronberger has been named manager at Dayton, O., and C. G. Farabee, manager of the Chattanooga, Tenn., district.

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Let us—as the inventors of the flexible shaft—put our 66 years of experience to work on your specific problems. In writing, please include the following data:

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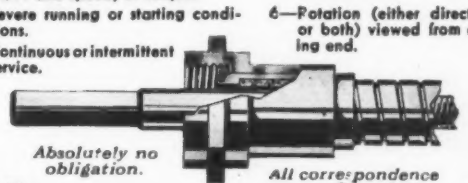
2—H. P. and speed, or torque.
3—Severe running or starting conditions.
4—Continuous or intermittent service.
5—Unusual external operating conditions.
6—Rotation (either direction, or both) viewed from driving end.



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NEW MACHINES—

And the Companies Behind Them

(For illustrations of other outstanding machinery, see Pages 90-91)

Bottling

Jar cooler-washer conveyor, Island Equipment & Supply Co. Inc., New York.

Ceramics

Unit type dust collector, Claude B. Schneible Co., Chicago.
Specific gravity separator, Sutton Steele & Steele Inc., Dallas, Texas.

Dairy

Small sized homogenizer, Homogenizer Corp., Ltd., Los Angeles.

Finishing

High frequency, self-contained brazing unit, Ajax Electrothermic Corp., Ajax Park, Trenton, N. J.
Metal parts washer, Sturdy-Bilt Equipment Corp., Milwaukee.
Vertical shell sprayer, Eclipse Air Brush Co. Inc., Newark, N. J.
*Portable wheelabrator, American Foundry Equipment Co., Mishawaka, Ind.

Heat Treating

Laboratory furnace, K. H. Huppert Co., Chicago.
Rapid oil coolers, Bell & Gossett Co., Morton Grove, Ill.
Electric heat treating furnace, Cleveland Electric Mfg. Corp., Indianapolis.

Industrial

*Gas engine driven compressor unit, The Cooper-Bessemer Corp., Mt. Vernon, O.
*Axial-flow fan, B. F. Sturtevant Co., Hyde Park, Boston.

Materials Handling

Conveyor for artillery shells, Rapids-Standard Co., Grand Rapids, Mich.
*Heavy-duty truck, Baker Industrial Truck Div., Cleveland.
Traveling scale car, Cleveland Tramrail Div., Cleveland Crane & Engrg. Co., Cleveland.
Sand-bag filler, Spinks Scale Co., Atlanta, Ga.
Fork truck, Clark Tructractor Div., Clark Equipment Co., Battle Creek, Mich.
Conveyor scale, Fairbanks Morse & Co., Chicago.
Shop truck, Buda Co., Harvey, Ill.
Hydraulic elevating table, Lyon-Raymond Corp., Greene, N. Y.

Metalworking

Lead screw tapping machine, Cleveland Tapping Machine Co., Cleveland.
300-ton hydraulic bending press, Lake Erie Engineering Corp., Buffalo.
Low temperature metal chiller, Motor Products Corp., North Chicago, Ill.
Multiple drill, Cleveland Pneumatic Tool Co., Cleveland.
Precision vertical bench miller, Duro Mfg. Co., Los Angeles.
Planetary milling machine, Plan-O-Mill Corp., Royal Oak, Mich.
Rotary gear shaver, Michigan Tool Co., Detroit.
Thread miller, Waltham Machine Works, Waltham, Mass.
Bar and tube straightening, sizing and polishing machine, Medart Co., St. Louis.
*Hydraulic drilling machine, Snyder Tool & Engineering Co., Detroit.

Road Building

*High-speed motor grader, J. D. Adams Co., Indianapolis.

Welding

20-ton heavy-duty welding positioner, Ransome Concrete Machinery Co., Dunellen, N. J.
Continuous, high-duty mass production welder, Ergolyte Mfg. Co., Philadelphia.
*Stationary welder, The Lincoln Electric Co., Cleveland.

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